University of Alberta

FACTORS AFFECTING POSTTRANSPLANT OUTCOMES IN PATIENTS BRIDGED TO CARDIAC TRANSPLANTATION ON VENTRICULAR ASSIST DEVICES

by

KIMBERLY SCHERR ©

A thesis submitted to the Faculty of Graduate Studies and
Research in partial fulfillment of the requirements
for the degree of MASTER OF NURSING.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **FACTORS AFFECTING POSTTRANSPLANT OUTCOMES IN PATIENTS BRIDGED TO CARDIAC TRANSPLANTATION ON VENTRICULAR ASSIST DEVICES** submitted by **KIMBERLY SCHERR** in partial fulfillment of the requirements for the degree of **MASTER OF NURSING.**

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August 12, 1997

Date

DEDICATION

I would like to dedicate this work to my husband, Darryl, who has provided me with ongoing love and support, and never lost faith that I would achieve my goals and dreams; and to my parents, Cornelius and Alva Bergen, who have given me the opportunity to pursue my career and given me love, support, and encouragement to become the person that I am today.

ABSTRACT

Ventricular assist devices (VADs) are used to sustain the lives of patients waiting on the cardiac transplant list who would otherwise die before a donor organ became available. This study described characteristics of patients bridged to cardiac transplantation on VADs, examined patient outcomes following transplantation, and identified factors that affected posttransplant outcomes. A retrospective chart analysis was used to study 20 adults placed on VADs between 1985 and the present. Seven patients received a cardiac transplant, 5 of the 7 survived to hospital discharge, and 4 are currently alive (mean length of survival = 915.71 days). Patient demographics, donor variables, measures of hemodynamic and respiratory status, and the presence of a cardiac arrest during the transplant waiting period were significantly related to posttransplant morbidity and mortality. Complications of VAD support necessitated the removal of several patients from the transplant list, however, patients who did survive to cardiac transplantation had favorable posttransplant outcomes.

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CHAPTER ONE

Introduction

Cardiac transplantation has become a widely accepted treatment modality for patients in end-stage cardiac failure. Quality of life posttransplant is excellent, as most patients are unrestricted in their activities and are able to perform at a capacity equal to or better than that achieved prior to their illness (Griffith, Hardesty, Trento, Kormos, & Bahnson, 1986; Pae, Pierce, Pennock, Campbell, & Waldhausen, 1987; Pae, 1987). The limiting factor to the number of heart transplants performed has always been the availability of donor organs. Each year, twenty to thirty percent of patients accepted for cardiac transplantation die while awaiting a donor heart (Ott, Mills, Eugene, & Gazzaniga, 1990, Pennington, McBride, Peigh, Miller, & Swartz, 1994; Pennington, McBride, Kanter, Miller, et al., 1989; O'Connell et al., 1988; Reedy, Ruzevich, Noedel, Vitale, & Merkle, 1990; Marks et al., 1992).

With recent technological advances, ventricular assist devices (VADs) are now being used to sustain the life of patients waiting on the transplant list who would have previously died before a donor organ became available. VADs have the ability to support the systemic and pulmonary circulation of patients in cardiogenic shock while they await an organ for transplantation. After transplantation, these patients are expected to live normal lives with generally excellent cardiac function and without long-term sequelae from the period of mechanical support (Kanter, Ruzevich, et al., 1988).

Patient selection criteria and timing issues surrounding insertion of VADs have been identified as critical factors affecting the ultimate survival of patients bridged to cardiac transplantation (Miller, Pae, & Pierce, 1990a; Takano, Taenaka, et al, 1989; Oaks, Pae, et al, 1991; Ott, Mills, Eugene, & Gazzaniga, 1990; Pennington, McBride, Swartz, Kanter, et al., 1989; Pennington, 1990; Pennington, McBride, Miller, & Swartz, 1994; Pennington, Farrar, Loisance, Pae, & Emery, 1993; Reedy, Swartz, et al., 1990; Noon, 1991; Farrar & Thoratec VAD Principal Investigators, 1994). Strict patient selection criteria are critical in the identification of appropriate candidates for VAD insertion and bridging to cardiac transplantation. In order to ensure that scarce donor organs are utilized appropriately, it is essential that outcomes of patients bridged to transplant on VADs closely approximate those of patients who are transplanted electively.

At the University of Alberta Hospital, patients who have VADs inserted for treatment of cardiogenic shock postcardiotomy or post-acute myocardial infarction may be urgently listed for cardiac transplantation. The multidisciplinary transplant team has a very short period of time in which to evaluate the patient for transplantation, and the basis of this assessment is physiological in nature. Therefore, it is prudent to identify those factors that may impact posttransplant outcomes and to assess each patient carefully with respect to these variables. This ensures that precious donor organs are transplanted into the most appropriate candidates and are not wasted in an attempt to salvage those who are not suitable for transplantation.

Currently at the University of Alberta Hospital, the Bio-Medicus centrifugal pump, Extracorporeal Membrane Oxygenation (ECMO), and the Hemopump are the types of VADs employed. Because of the lack of availability of devices capable of long-term support in this institution, the ability to bridge patients for extended periods of time to allow for careful assessment of secondary organ dysfunction, and to determine if other contraindications to cardiac transplantation exist, is limited.

Nurses at the bedside must believe that "bridge to transplant" procedures will benefit patients on VADs and not cause undue pain and suffering in order to provide the comprehensive care that is required. For this reason, it is important that specific research-based criteria be used as the basis for patient consideration and selection as potential transplant recipients. This ensures that patients who are bridged to transplant and their families have reasonable expectations for positive posttransplant outcomes. If bedside nurses agree that a bridging procedure is in the patient's best interest, they are better able to provide support, encouragement, and reinforcement to patients and their families and to provide them with realistic expectations of the bridging procedure.

Numerous studies conducted on the use of VADs as a bridge to cardiac transplantation have produced contradictory findings. Certain patient variables have been found to be significant in some samples for outcomes posttransplant, while they are nonsignificant in others. A study of preoperative risk factors, analysis of VAD selection and application, and posttransplant outcomes provides the basis by which to improve patient selection, provide comprehensive care to the bridged patient, and ultimately improve long-term survival rates after cardiac transplantation. In view of the decreasing availability of donor organs, it is important to critically analyze outcomes obtained with VADs to ascertain their effectiveness and to determine if the continued use of precious donor organs in patients bridged to transplant on these devices is justified (Kanter, McBride, et al., 1988).

Purpose of the Study

The purpose of this study was to examine factors present in adults bridged to cardiac transplantation with VADs that impacted posttransplant outcomes. The following questions were addressed:

a. What were the characteristics of patients who had a VAD inserted as a bridge to cardiac transplantation?
b. What were the outcomes of patients bridged to cardiac transplantation on VADs?
c. What factors affected posttransplant outcomes in patients bridged to cardiac transplantation on VADs?

The results attained were analyzed to provide a description of patients bridged to cardiac transplantation and to provide information regarding the effectiveness of the VADs currently used. The findings provide a Canadian perspective to the existing knowledge in this field and allow comparisons to be made with American and International data. In addition, the data from this patient population verifies existing research findings and provides impetus for further improvements in care of the bridged patient.

Significance of the Study

With improved patient selection for bridging to transplant, only patients with a reasonable chance of survival in the perioperative period are accepted and listed for cardiac transplantation. Other patients are allowed to die with dignity and without the pain and suffering that often accompany a slow, progressive deterioration.

Nursing staff are knowledgeable regarding specific variables that make positive outcomes more likely following a bridging procedure and are better able to educate patients and families about expected outcomes, and provide support and encouragement during this critical period. In addition, nurses have insight into the decisions that are made regarding patient care, and are in a better position to advocate for the patient and family. This has improved their ability to work closely with the transplant team to provide a holistic approach in caring for patients bridged to cardiac transplantation on VADs. In turn, the burden that is felt by families making decisions regarding consent for or termination of treatment has diminished. Transplant personnel who observe candidates deteriorate and die while awaiting a transplant have renewed confidence that donor organs are allocated to patients who are most likely to benefit from the surgery and not wasted in an attempt to salvage inappropriate transplant candidates.

CHAPTER TWO

Literature Review

As the complement to several years of experimental animal research, hours of practice to perfect the surgical technique, and the recognition of the immunologic factors and pathologic features of rejection limiting survival, the first human cardiac transplantation was performed in Cape Town, South Africa by Dr. Christiaan Barnard in 1967 (Reitz, 1990). Subsequent attempts were hampered by difficulty in controlling rejection and infection episodes, and not until the advent of the immunosuppressive drug, Cyclosporine, in 1981, did attempts at cardiac transplantation meet with success. As a result, the numbers of transplants performed worldwide increased significantly.

The development and clinical application of circulatory support has closely paralleled the development of cardiac transplantation (Pennington, McBride, Peigh, et al., 1994). The first attempt at bridging to transplant was made by Dr. Denton Cooley in 1969 with the total artificial heart (TAH) (Cooley et al., 1969). Though this attempt was unsuccessful, the feasibility of this approach was demonstrated and became the basis by which further attempts at bridging would be made. In 1981, Cooley and colleagues again attempted the use of the TAH as a bridge to transplant with no long-term survivors (Joyce, Emery, et al., 1989). Dr. Keith Reemtsma and colleagues performed the first successful bridge to cardiac transplantation with the intra-aortic balloon pump in 1978 (Reemtsma et al., 1978).

The modern era of bridging to cardiac transplantation began in 1984 with the first successful use of the TAH by Dr. Jack Copeland; the Pierce-Donachy (Thoratec) VAD by Dr. Donald Hill and coworkers; and the Novacor electrical VAD by Oyer, Starnes, and colleagues respectively (Kanter, Ruzevich, et al., 1988; Pennington, McBride, Kanter, Miller, et al., 1989). Successes in device implantation have been dependent on patient selection, surgical skill, and the availability of a low-risk prosthetic blood pump (Hill, 1989).

Physiology of VAD Use

An injury to the myocardium results in ineffective emptying of the failing left ventricle during systole. Cardiac output decreases resulting in a lower systemic perfusion pressure. An increase in left ventricular end-diastolic pressure inhibits left atrial filling causing an increase in pulmonary venous pressure and subsequently, pulmonary congestion. Pulmonary congestion reduces arterial oxygen tension and inhibits tissue perfusion. Severe metabolic acidosis ensues, further restricting cardiac function and if not reversed, vasopressor-resistant hypotension, hypoxemia, arrhythmias, and death result (DeBakey, 1971).

The goal of mechanical circulatory support is to decompress the hypokinetic ventricle, decrease myocardial work, and reduce oxygen demand while maintaining adequate systemic perfusion and coronary blood flow to provide time for the metabolic recovery of the injured or "stunned" myocardium (Pae, Pierce, Pennock, et al., 1987; Miller, Pae, & Pierce, 1990b; Takano, Taenaka, et al., 1989; Verani et al., 1989; Pae, Pierce, et al., 1987; Pae, 1987; Rountree, 1991; Ballantyne, Verani, Short, Hyatt, & Noon, 1987; Magovern, Golding, Oyer, & Cabrol, 1989; Pae, Miller, Matthews, & Pierce, 1992; Park et al., 1986; Pennock, Pierce, Wisman, Bull, & Waldhausen, 1983). VAD implementation reduces preload and decreases myocardial wall tension and oxygen consumption (Park et al., 1986). Left ventricular end-diastolic pressure is decreased, strain on the myocardium is reduced, and pulmonary congestion is relieved with improvement in arterial oxygen tension. The resultant prompt increase in cardiac output and in coronary flow of well-oxygenated blood to the myocardium enhances recuperability of the myocardium and improves left ventricular function (Holman, Bourge, McGiffin, & Kirklin, 1994). Ventricular assist pumping can support either the systemic and pulmonary circulation individually, or both together (Pae, Pierce, et al., 1987).

Recipient Selection

The insertion of a VAD is warranted when the following parameters (Table 2.0) are present despite maximal pharmacologic intervention with optimal preload and institution of an intra-aortic balloon pump (Norman et al., 1977; Pennington, McBride, Miller, et al., 1994; Moore, Dailey, Canon, & Rubin, 1992; Oaks, Wisman et al., 1989; Drinkwater &

Laks, 1988; Pierce, 1983; Reedy, Ruzevich, et al., 1990; Frazier, Macris, Wampler, et al., 1990; Pennington, Joyce, Pae, & Burkholder, 1989; Takano, Nakatani, & Taenaka, 1993; Pennington & Tehmuhlen, 1989).

Table 2.0

Hemodynamic Indications for VAD Implantation

1. Systemic hypotension with a mean arterial pressure (MAP) < 60 mmHg or systolic blood pressure < 90 mmHg
2. Cardiac index (CI) < 2.0 L/minute/m^2
3. Pulmonary capillary wedge pressure (PCWP) or right atrial pressure (or both) > 20 mmHg
4. Systemic vascular resistance > 2100 dynes/second/cm^5
5. Urine output < 20 mls/hour

At the University of Alberta Hospital, maximal pharmacologic support includes the use of two to four inotropic agents in doses at, or exceeding, the maximum recommendations for each drug. Patients selected for bridge to transplant procedures must also meet the criteria for cardiac transplantation at the time of implantation of the device.

Patients with end-stage cardiac disease with no reasonable treatment alternatives are considered for transplantation. Table 2.1 documents criteria that patients must meet in order to become transplant candidates (Shinn, 1991; Ley, 1991; Copeland, Emery, Levinson, McAleer, & Riley, 1985; Reedy, Swartz, et al., 1990; Hill, Farrar, et al., 1986; Ott, Mills, Eugene, & Gazzaniga, 1990; Joyce, Kiser, et al., 1990).

Table 2.1

Criteria for Cardiac Transplantation

1. Age < 65 years
2. Absence of uncontrollable systemic infection
3. Absence of other chronic, systemic illness
4. Lack of irreversible renal or hepatic dysfunction
5. Absence of fixed pulmonary hypertension
6. Absence of massive hemorrhage or uncontrollable coagulopathy
7. Absence of a recent cerebrovascular event
8. Knowledge of a patient's psychosocial profile

Relative contraindications to VAD insertion as a bridge to transplantation include recent pulmonary embolism, recent gastrointestinal hemorrhage, significant peripheral vascular disease, severe emphysema and/or chronic obstructive pulmonary disease, drug addiction, alcohol addiction, inadequate psychosocial support, or presence of any other condition that may limit posttransplant survival (Cabrol, Solis, et al., 1989; Kanter, McBride, et al., 1988; Pennington & Termuhlen, 1989). The risk of complications that may preclude transplantation must be balanced against the potential efficacy of this therapeutic approach in treating patients with no other chance for survival (Hill, Farrar, et al., 1986).

Patients considered for bridge to transplant on VADs include patients who cannot be weaned from cardiopulmonary bypass following a cardiac surgical procedure; patients in cardiogenic shock following acute myocardial infarction; patients with end-stage cardiomyopathy who are deteriorating while waiting on the transplant list; and patients who have acute rejection or immediate donor organ failure after transplantation (Ley, 1991; Drinkwater & Laks, 1988; Miller, Pae, & Pierce, 1990b; Oaks, Pae, et al., 1991; Pae, Miller, & Pierce, 1989; Keon, Koshal, & Menkis, 1986). Approximately 1% of postcardiotomy patients will require aggressive circulatory support, the majority of which have had isolated coronary artery bypass grafting (Pae, 1993; Parascandola et al., 1988; Rutan, 1991; Smith & Cleavinger, 1991; Pennock, Pierce, Wisman, et al., 1983; Adamson, Dembitsky, Reichman, Moreno-Cabral, & Daily, 1989; Miller, Pae, & Pierce, 1990a; Pennington, Merjavy, et al., 1985).

Patients requiring VAD insertion due to the inability to be weaned from cardiopulmonary bypass following cardiac surgery are less favourable candidates for bridging to transplantation because the patients are generally unknown to the transplant service. Meaningful evaluation is difficult, if not impossible, due to the critical nature of the patient's condition. Postcardiotomy patients are at higher risk for complications, such as bleeding and infection, due to the recent invasive procedure and prolonged cardiopulmonary bypass times (Bolman, Cox, et al., 1989). For those patients who are not candidates for transplantation, the surgeon must ensure that a technically correct surgical repair has been performed prior to committing the patient to circulatory assist pending recovery of the native heart.

Types of VADs

Intra-aortic Balloon Pump

The intra-aortic balloon pump (IABP) is the most frequently used and least complicated means of instituting circulatory assistance. Clinically, the IABP is most often used for temporary support of acute reversible left ventricular failure after cardiac surgery and cardiogenic shock post-acute myocardial infarction. Most commonly inserted via percutaneous femoral puncture, the balloon is situated within the aorta and has been shown to increase diastolic filling of the coronary arteries and to decrease afterload by inflation after aortic valve closure and deflation just prior to systole (Smith & Cleavinger, 1991; Copeland, Emery, et al., 1985). Cardiac output may be augmented by approximately 10-15% (Reedy, Ruzevich, et al., 1990).

The advantages of IABP include ease of insertion and use, low cost, availability with experience in its use, and lack of necessity for anticoagulation. Disadvantages include a complication rate of 20% (i.e. compromise of lower extremity/renal perfusion, failure of insertion, infection, arterial laceration/dissection, bleeding, thrombosis, thrombocytopenia); limited increase in cardiac output; lack of effect on preload reduction; inability to support the right ventricle; and limited effectiveness with tachycardia and dysrhythmias (Smith & Cleavinger, 1991; Copeland, Emery, et al., 1985).

Roller Pump

Roller pumps were initially used as VADs because of the ease of adaptation from standard heart-lung bypass machines (Ott, Mills, Eugene, & Gazzaniga, 1990; Koffsky, Litwak, Mitchell, & Jurado, 1978). The system, which consists of elastomer cannulae, an extracorporeal tubing loop, and rotating pump, is able to provide up to 5 litres per minute of nonpulsatile flow (Litwak et al., 1977). Simplicity, availability, and low cost are cited as the main advantages of roller pump systems. Difficulties include cannula obstruction and cavitation with resultant air embolism, the need for anticoagulation, blood trauma and thromboembolism due to the shear forces generated, flow limitations, and nonpulsatility (Magovern, 1993; Pae, 1987; Wesolowski, 1966).

Centrifugal Pump

Centrifugal vortex pumps such as the Bio-Medicus and Sarns 3M are the most popular VADs on the market because of their simplicity, accessability, easy applicability to standard heart-lung circulation cannulae, ability to generate high flows, less blood trauma, and relatively low cost (Pae, 1987; Bolman, Cox, et al., 1989; Drinkwater & Laks, 1988; Smith & Cleavinger, 1991; Killen, Piehler, Borkon, & Reed, 1991; Ott, Mills, Eugene, & Gazzaniga, 1990; Curtis, et al., 1990). Centrifugal pumps provide nonpulsatile flow with an electrically powered magnetic impeller (Kanter, Ruzevich, et al., 1988; Golding, Stewart, Sinkewich, Smith, & Cosgrove, 1988; Pennington, Bernhard, et al., 1985; Pennington, 1980). Centrifugal force is used to generate energy which causes the blood to rise from the pump head's base, forcing a return direction of flow (Quaal, 1991). Pump output is proportional to revolutions per minute and is capable of total circulatory support (Golding, Crouch, et al., 1992). Difficulties with centrifugal devices include nonpulsatile flow which leads to end-organ dysfunction during prolonged perfusion, the need for full anticoagulation to counteract thromboembolic complications and traumatic hemolysis, intensive monitoring requiring a perfusionist to be available 24 hours a day, and lack of mobility with current median sternotomy cannulation techniques (Ott, Mills, Eugene, & Gazzaniga, 1990; Smith & Cleavinger, 1991; Unger et al., 1984). Limited durability of the pump head limits long-term use (Quaal, 1991), although the device has been used for a period of 31 days with successful transplantation (Golding, Stewart, et al., 1988; Magovern, Golding, et al., 1989). Though nonpulsatility has been cited as a disadvantage of centrifugal devices, Golding (1984) states that the chronic depulsed state provided by these pumps is compatible with the maintenance of normal organ function provided that appropriate flows and pressures are maintained.

Extracorporeal Membrane Oxygenation

ECMO or cardiopulmonary support (CPS) is another type of mechanical assist device which supports cardiac and pulmonary functions during heart or lung failure (Smith & Cleavinger, 1991). ECMO consists of a membrane oxygenator and heat exchanger in line with either a roller pump or centrifugal pump (Kanter, Ruzevich, et al., 1988; Kanter, Pennington, et al., 1987; Reichman et al., 1990). A percutaneous cannulation technique is used to gain vascular access to the proximal and distal femoral artery and vein. Venous blood is removed from the central circulation, warmed, oxygenated, and then returned to the femoral artery (Bavin, 1991). Primary indications for use are percutaneous transluminal coronary angioplasty and emergency cardiopulmonary support for full or impending cardiac and/or pulmonary failure.

Survival rates for those patients in full-blown cardiac arrest are dismal at 4% to 27% (Bavin, 1991; Mooney et al., 1991). Due to these poor survival statistics, unwitnessed cardiac arrest and prolonged cardiopulmonary resuscitation are contraindications to this type of support (Hill, Bruhn, et al., 1992). ECMO requires continuous heparinization and therefore is unsuitable for postcardiotomy patients. Best results are achieved with institution of ECMO within thirty minutes of insult and use of this device is not recommended beyond 24 hours (Moore et al., 1992; Bavin, 1991; Raithel et al., 1989). Reedy, Swartz, Raithel, Szukalski, and Pennington (1990) suggested that ECMO is useful for intervals of 12 to 24 hours and can be best applied to patients younger than 60 years of age, patients with acute events amenable to surgical intervention, and candidates for cardiac transplantation who could be switched to a more sophisticated method of support within 12 to 24 hours of institution of ECMO.

ECMO offers the advantage of simple, rapid insertion without the need for a thoracic incision, provides access to portable bypass outside of the operating room, has the potential to support both the pulmonary and systemic circulations, and provides time to evaluate the patient's status as a transplant candidate (Pennington, Merlahn, et al., 1984; Smith & Cleavinger, 1991). Complications are largely related to the inability to gain vascular access sites in approximately 10% of patients (Dembitsky, Moreno-Cabral, Adamson, & Daily, 1993).

Hemopump

The Hemopump consists of a high-speed rotary pump contained in a perfusion cannula inserted across the aortic valve into the left ventricle (Moritz & Wolner, 1993). The system is powered and flushed through an axial cable and may provide up to 4 litres/minute of left ventricular support (Phillips, Barker, et al., 1990; Deeb et al., 1990). Small size, ease of insertion without a sternotomy incision, relatively low cost, and minimal invasiveness make this device desirable for use (Frazier, Macris, Wampler, et al., 1990; Smith & Cleavinger, 1991; Rountree, 1991; Burnett, et al., 1990). Because the Hemopump offers only left-sided support, patients with cardiomyopathy and biventricular failure may not sufficiently benefit from this device.

Pulsatile VADs represent the newest and most advanced forms of mechanical support. They portray a significant improvement over extracorporeal devices primarily because of biocompatible blood-contacting surfaces which allow for extended use with minimal hemolysis and anticoagulation (Ott, Mills, Eugene, & Gazzaniga, 1990). With the expectation that patients will require longer periods of VAD support due to shortages in donor organs, pulsatile devices have demonstrated advantages, however, in comparison to the nonpulsatile support systems they are much more complex and costly. Pulsatile perfusion allows for more efficient metabolism at lower flow rates; improved capillary perfusion; less metabolic acidosis; increased oxygen consumption; lower peripheral arterial resistance; better renal, cerebral, and myocardial perfusion; less hepatocellular injury; and preservation of the endocrine balance (Mavroudis, 1978; Bregman, 1978).

External Pulsatile VADs

The Pierce-Donachy (Thoratec) VAD, the Symbion Acute VAD (AVAD), and the Abiomed BVS 5000 are paracorporeal, pneumatically activated prosthetic ventricles (Kanter, McBride, et al., 1988; Kanter, Ruzevich, et al., 1988; Oaks, Wisman, et al., 1989; Copeland, Emery, et al., 1985; Farrar & Thoratec VAD Principal Investigators, 1994; Ley, 1991; Magovern & Pierce, 1990). These devices are versatile and may be used for univentricular or biventricular support; cannulation may be achieved by left atrial or ventricular access; the paracorporeal approach allows their use in a wide range of body sizes; and they may provide support pending recovery of the myocardium or as a bridge to transplantation (Farrar & Hill, 1993).

The Thoratec VAD and Symbion AVAD rest on the abdominal wall with the inlet and outflow cannulas traversing the anterior abdominal wall via percutaneous cannulae that pump blood in parallel with the native circulation (Ott, Mills, Eugene, & Gazzaniga, 1990; Ott, Mills, & Eugene, 1989). The Symbion's pump output is restricted to approximately 5 litres/minute, therefore its limitation to patients weighing 80 kilograms or less is warranted (Lick et al., 1993). In addition, thromboembolism is of major concern with the Symbion AVAD with a reported incidence of 78% (Icenogle et al., 1989).

The Abiomed BVS 5000 VAD uses a microprocessor-controlled pulsatile pneumatic drive system that simulates normal physiologic mechanical cardiac function by external pulsatile flow (Dixon & Farris, 1991; Champseur et al., 1990). The pumping chambers do not lie in a paracorporeal position, but rather are mounted on an intravenous pole near the patient (Ott, Mills, Eugene, & Gazzaniga, 1990). The major limitation to this device is the external alignment of the pumping chamber which impedes early mobilization of the patient.

Advantages of external pulsatile VADs include the ability to provide right, left, or biventricular support for extended periods of time; patient mobility; versatility; utility on smaller patients; feedback and control of device cardiac output; and simplicity of implantation technique (Smith & Cleavinger, 1991). Pulsatile devices reduce the need for systemic anticoagulation; they minimize blood trauma and the potential for thromboembolism; and they provide complete physiologic support of the systemic and pulmonary circulations, either together or independently (Pae, 1987).

Implantable VADs

Implantable VADs are prototypes of permanently implantable devices. These heterotopic devices provide pulsatile flow while allowing for early mobilization of patients. They have the ability to provide support for prolonged periods of time and are capable of producing high cardiac outputs (Smith & Cleavinger, 1991). These devices are technically more complex to insert, have potential "fit" problems in smaller patients, and provide only left ventricular support (McCarthy et al., 1991). The biggest advantage of the implantable system is the ability to mobilize the patient (Portner, Baumgartner, Cabrol, & Frazier, 1993) thereby promoting wound healing; reducing the risk of infection; preventing loss of endurance, coordination, and strength; and decreasing the incidence of respiratory, gastrointestinal, genitourinary, and psychological complications associated with bedrest in bridged patients (Reedy, Swartz, Lohmann, et al., 1992; Shinn, Abou-Awdi, Ley, Reedy, & Rountree, 1993). With the use of implantable devices, improvements in quality of life may be enhanced by bridging patients in an outpatient setting (Dew et al., 1993).

The Novacor left ventricular assist system (LVAS) is an electrically operated dual pusher plate sac type pump that is implanted in the abdominal wall just anterior to the posterior rectus abdominis sheath (Kanter, McBride, et al., 1988; Pennington, McBride, Kanter, Miller, et al., 1989; Copeland et al., 1985). A cable exits the abdominal wall through a subcutaneous tunnel and serves as a power drive line, an air vent, and a monitoring system. The Thermo Cardiosystems Heartmate is an implantable pneumatic device with an external control console (Abou-Awdi, 1991; Frazier, 1993; Burton et al., 1993). It has a textured blood contact surface designed to reduce the thromboembolic potential (Ott, Mills, Eugene, & Gazzaniga, 1990; Frazier, Duncan, et al., 1992). Both devices are designed for left ventricular apical implantation only and cannot be used with left atrial cannulation or for right ventricular support. They have been used to provide temporary circulatory support to patients with potentially reversible myocardial dysfunction, however the primary indication for use is bridging to transplantation (Shinn, 1991).

The Novacor LVAS is contraindicated in patients with mechanical aortic valves in situ because of the potential for thrombus development on the valve which rarely opens during normal LVAS operation (McCarthy et al., 1991). The major advantage of the Novacor LVAS is the capability to produce high cardiac outputs (greater than 9 litres/minute). Disadvantages of the Thermedics Heartmate include difficulty in implantation; requisite dissection of the diaphragm from the chest wall and extensive dissection of the anterior abdominal wall for implantation; and the need for continuous anticoagulation with major potentials for bleeding and wound complications. The Thermedics Heartmate has been used successfully to support the failing circulation for greater than 30 days (McGee et al., 1989).

Total Artificial Heart

The total artificial heart is a pair of pneumatically driven ventricles, each composed of a blood sac enclosed in a rigid housing in which air is introduced and withdrawn in pulses. Pneumatic drive lines connect the TAH to its external power source and a computerized system monitors the pumps (Pennington, McBride, Swartz, et al., 1989). Use of the TAH requires that the native ventricles be excised. The remaining atria are used to secure the mechanical ventricles in place (Pennington, Swartz, et al., 1989).

The TAH provides complete control of the cardiovascular system by producing cardiac outputs of up to 8-10 litres/minute, allows patient mobility, and has the ability to reverse end-organ failure (Smith & Cleavinger, 1991). Limiting factors in the application of this device as a temporary or permanent cardiac replacement include complications with fit, bleeding, thromboembolism, infection, and multi-organ failure (Johnson, Liska, Joyce, & Emery, 1992; Kunin et al., 1988; Davis, Rosenberg, Snyder, & Pierce, 1989; Griffith, 1989; Levinson et al., 1986). Patients on TAHs are limited to cardiac transplantation as their only surgical option, therefore the devices must be inserted in candidates with no contraindications to transplantation (Barker, 1991; Loisance et al., 1989). Cabrol, Gandjbakhch, et al. (1988) stated that the best candidates for the TAH as a bridge to transplant are patients less than 45 years of age with recent, acute intractable heart failure, reversible organ dysfunction, and without any contraindications to transplantation.

A greater number of options for meeting the needs of circulatory support in individual patients exists when considering the heterotopic approach to bridging to transplant (insertion of a device in series with the intact native heart) versus the orthotopic approach used with the TAH. Leaving the natural heart in situ allows for the possibility of cardiac function recovery or other surgical intervention. Heterotopic devices may be tailored to the specific needs of each individual and are not restricted to large patients, as are the TAHs. In addition, heterotopic ventricles may be inserted without the use of extracorporeal circulation in some circumstances (Farrar, Hill, Gray, Pennington, et al., 1988). However orthotopic ventricles are indicated in certain clinical situations. These include a ventricular septal defect occurring after myocardial infarction involving the septum, the presence of an intraventricular or intraatrial thrombus, or the presence of severe valvular dysfunction (Koshal, Masters, Hendry, & Keon, 1991).

Risk Factors and Complications Associated with VAD Use

Several studies concluded that the early survival rate of patients bridged to transplant on VADs closely approximates that of patients transplanted electively, provided that patients have been carefully selected (Farrar, Hill, Gray, Pennington, et al., 1988; Cabrol, Solis, et al., 1989; Marks et al., 1992; Hardesty et al., 1986; Peric, Frazier, Macris, & Radovancevic, 1986; Bolman, Cance, et al., 1988; Bolman, Spray, et al., 1987; O'Connell et al., 1988; Reedy, Swartz, et al., 1990; Adamson et al., 1989; Birovljev, et al., 1992; Farrar, Lawson, Litwak, & Cederwall, 1990; Farrar & Hill, 1993; Reedy, Pennington, et al., 1992). Joyce, Emery, et al. (1989) reported a 30-day posttransplant survival rate of 91% and a long-term survival rate of 82% in the group of patients who were mechanically bridged to cardiac transplantation. Bolman, Cance, et al. (1988) reported a 12 and

24 month survival of 87% which was virtually identical to the nonsupported patient group. Actuarial survival of patients who were successfully transplanted following a bridge procedure has been reported as 100% at 3,6, and 12 months respectively, and 71% at 24 months (Bolman, Cox, et al., 1989). Farrar, Hill, Gray, Pennington, et al. (1988) cited a one year survival rate of 92%. Farrar, Hill, and the Thoratec VAD Principal Investigators (1995) reported that even though patients require biventricular support as the severity of illness increases, patients supported on univentricular or biventricular devices have posttransplant survival rates comparable to that of conventional cardiac transplantation.

Other research contradicts these findings concluding that patients requiring pretransplant mechanical support are at higher risk for death posttransplant (Johnson, Prieto, Joyce, Pritzker, & Emery, 1992; Stevenson, Donohue, et al., 1987; Miller, Pae, & Pierce, 1990b). Walley et al. (1993) reported a 39.1% in-hospital mortality for patients requiring pretransplant mechanical support. Pae, Miller, and Pierce (1989) reported survival rates of bridged patients clearly less favourable overall than the routine, more elective candidates (62% versus 79% one year survival as reported in the combined ASAIO-ISHT Registry). In a study of 186 patients bridged to transplant on Thoratec VADs, Farrar and the Thoratec VAD Principal Investigators (1994) found the overall survival from VAD implantation to discharge was 52%. Results of this study showed that survival to transplant with VAD support is in the range of 62% to 65%.

Patient selection criteria must be applied at two critical stages: the time of VAD placement and the time of cardiac transplantation (Pennington, McBride, Kanter, Miller, et al., 1989). A strict policy for cardiac transplantation must be applied to patients subjected to bridge to transplant procedures with the definitive operation delayed until the patient's condition appears adequate and stable (Pennington, Swartz, et al., 1989). Ideally, patients to be bridged should be transplant candidates prior to VAD implantation since it is difficult to determine the suitability of a patient for transplantation once insertion of the device has been accomplished. Multi-system recovery must be complete prior to undertaking transplantation in these patients. Under such conditions, survival rates of those bridged to cardiac transplantation should be equivalent to those achieved in the conventional cardiac transplant population.

Several variables have been identified in the literature as having an effect on posttransplant survival. Demographics and physiological characteristics of the recipient before VAD implantation, after VAD implantation, prior to transplantation, and following transplantation, in addition to device and donor-related variables have been identified as important factors in the ultimate survival of the cardiac transplant recipient (Bourge et al., 1993). These variables have been categorized as pre-VAD risk factors, device-related risk factors, complications of VAD support, and donor-related risk factors.

Pre-VAD Risk Factors

Age. Significant risk factors for death in the bridged population include very young recipient age (less than 5 years) and advanced age (greater than 60 years) (Bourge et al., 1993). Cabrol, Solis, et al. (1989) studied a population of patients who were bridged to transplant on a TAH. Their results showed that of younger patients (less than age 40), 56% had successful transplantation as opposed to 17.6% of patients older than 40 years of age. In a retrospective study of predictors of weaning and survival post-VAD implant in 79 patients, Golding, Crouch, et al. (1992) also found that age had an effect on survival but only when considered as greater than or equal to 50 years or less than 50 years. Forty-two percent of patients less than 50 years were discharged from hospital compared to 20% in the older age group.

In a study on the salvage of 41 cardiac surgical patients with the Bio-Medicus centrifugal VAD by Killen, et al. (1991), several preoperative variables were evaluated with respect to survival post-VAD implant. A significant improvement in survival was reported in younger patients (age 39 to 63 years) when compared to the older population (age 64 to 83 years). As the patient's age increased, the chance that the patient would be successfully weaned from support and discharged from hospital was significantly decreased (Miller, Pae, & Pierce, 1990a).

Farrar, Lawson, et al. (1990) described a significant improvement in survival in patients younger than 42 years of age. Adamson et al.

(1989) reported that age less than 60 years was statistically significant for survival, while no difference in survival based on sex was noted. On the other hand, Magovern (1993) and Pennington, McBride, Peigh, et al. (1994) found no significant differences between survivors and nonsurvivors post-VAD support in respect to age.

Gender. In the previously described study on the salvage of 41 cardiac surgical patients with the Bio-Medicus centrifugal VAD, no significant difference in survival was found when comparing males and females (Killen et al., 1991). Magovern (1993) and Pennington, McBride, Peigh, et al. (1994) concurred that no significant differences existed between survivors and nonsurvivors post-VAD support with respect to gender. In another series, Farrar, Lawson, et al. (1990) reported a significant improvement in survival in males (77%) as compared to females (56%).

Diagnosis. Cabrol, Solis, et al. (1989) studied a population of patients who were bridged to transplant on TAHs. They discovered that of those patients with acute cardiac decompensation, survival rates posttransplant were equal to 44%, as opposed to those with chronic disease who had a 29.4% survival rate. In this study, patients with cardiomyopathy as their diagnosis fared better following transplantation than did those with ischemic heart disease (46.2% versus 33%). Killen et al. (1991) reported no significant difference in survival by extent of coronary disease. Pennington, McBride, Peigh, et al. (1994) found no significant differences between survivors and nonsurvivors post-VAD support with respect to etiology of cardiac failure.

Previous Cardiotomy. In the study by Farrar and the Thoratec VAD Principal Investigators (1994), a significant history of cardiac surgery performed greater than 30 days prior to VAD insertion was present in the nonsurvivors. Pennington, Farrar, et al. (1993) also reported a decrease in survival in patients with previous cardiac surgeries. A survival rate to transplantation of 33% was found in the group with prior cardiac surgery versus 67% in the group with no prior surgeries.

Killen et al. (1991) found no significant difference between survivors and nonsurvivors when comparing number of previous cardiac surgeries in 41 patients supported on the Bio-Medicus centrifugal pump, and Magovern (1993) similarly reported no significant influence on survival by primary cardiac surgical procedure performed. McCarthy, Smedira, et al. (1996) reported a 90 to 94.3% one year survival rate in patients bridged to transplant on the Heartmate LVAD following cardiac surgery. In relation to posttransplant survival, the occurrence of postoperative complications was similar between patients who had had previous cardiac surgeries and those who had not (McBride, Swartz, et al., 1990).

Urgency of Procedure. A retrospective study of predictors of weaning and survival post-VAD implant in 79 patients conducted by Golding, Crouch, et al. (1992) found that when the pretransplant operative procedure was elective, there was a significant difference for weaning from VAD support, but not survival, when compared to emergency procedures. Killen et al. (1991) found no significant difference in survival by urgency of operation.

Cardiac Arrest. Cardiac arrest necessitating cardiopulmonary resuscitation has been found to negatively influence survival of patients on VAD support (Reedy, Swartz, et al., 1990). Incidence of pre-VAD arrhythmias and multiple cardiac arrests is a predictor of subsequent development of ventricular fibrillation while on the device. In a study conducted by Farrar, Hill, Gray, Galbraith, et al. (1989), 71% of patients with preimplant arrhythmias and multiple cardiac arrests exhibited postimplant arrhythmias compared to 30% in patients without preimplant arrhythmias. Prior cardiac arrest/hemodynamic collapse has thus been identified as a statistically significant risk factor for death following mechanical circulatory support (Guyton et al., 1993; Joyce, Johnson, et al., 1988).

Hemodynamic Status. In a study on the salvage of 41 cardiac surgical patients with the Bio-Medicus centrifugal VAD by Killen et al. (1991), preoperative hemodynamic status was similar in both the survivors and nonsurvivors posttransplant. Similarly, Pennington, McBride, Peigh, et al. (1994), discovered no significant differences between survivors and nonsurvivors post-VAD support with respect to predevice hemodynamics. Examination of hemodynamic data pre-VAD insertion showed no relationship to predictability of which patients would have favourable outcomes with univentricular support (Kormos, Borovetz, et al., 1990).

Cardiopulmonary Bypass Time. Timely implantation of the support device avoiding multiple attempts to wean the patient off extracorporeal circulation was a positive predictor for outcome (Moritz & Wolner, 1993; Pennock, Pierce, Wisman, et al., 1983; Pierce, Parr, et al., 1981; Takano, Taenaka, et al., 1989; Anstadt et al., 1992; DeRose, et al., 1997). Farrar, Hill, Gray, Pennington, et al. (1988) concluded that poor patient selection and the late institution of circulatory support are major factors in the inability to reverse ischemic end-organ damage. The inability to wean patients from mechanical support following lengthy cardiopulmonary bypass is explained by an increased incidence of perioperative bleeding and disseminated intravascular coagulopathy (DIC) leading to subsequent multi-organ dysfunction (Parascandola, et al., 1988; Park et al., 1986).

Killen et al. (1991) described no significant differences in survival by time of VAD insertion or total duration of cardiopulmonary bypass. Furthermore, Magovern (1993) reported no significant influence on survival by time of aortic cross-clamp. In addition, no significant difference was found between the mean length of time of circulatory support and whether or not a patient was weaned from the device or subsequently discharged from hospital (Pae, Miller, Matthews, et al., 1992).

Perioperative Myocardial Infarction. Perioperative myocardial infarction has been identified as a significant univariate determinant of survival (Parascandola et al., 1988; Magovern, Golding, et al., 1989). Nonsurvivors of mechanical circulatory support had an infarction rate of greater than 70% (Ruzevich et al., 1988). Perioperative ischemia, inadequate myocardial preservation, incomplete myocardial revascularization, and reperfusion injury have been cited as possible theories for temporary ventricular failure (Rose et al., 1983).

Myocardial infarction within 24 to 48 hours of surgery was a strong deterrant to survival due to the frequent lack of myocardial recovery (Pennington, Joyce, et al., 1989; Pennington, McBride, Swartz, et al., 1989). However acute myocardial infarction does not always preclude improvement in ventricular function, therefore one cannot exclude patients from VAD placement based on this factor alone (Pennington, McBride, Kanter, Swartz, et al., 1988).

Respiratory Failure. A significant risk factor for death posttransplant in bridged patients is the presence of ventilatory support at the time of cardiac transplant (Bourge et al., 1993). Swartz et al. (1994) found the number of days intubated to be a statistically significant predictor of mortality in univariate analysis. Pulmonary insufficiency requiring a FiO_2 of greater than .70 and the need to be intubated for greater than 5 days are factors that can negatively influence survival (Reedy, Swartz, et al., 1990).

Renal Dysfunction. Abnormal renal function has been reported to significantly increase the risk for poor posttransplant outcomes (Bourge et al., 1993). Golding, Crouch, et al. (1992) found predevice blood urea nitrogen (BUN) and creatinine levels to be significant in regards to ability to wean patients from the VAD.

Blood Urea Nitrogen. An analysis of pre-VAD demographic, hemodynamic, and blood chemistry variables was done by Farrar and Thoratec VAD Principal Investigators (1994) in 186 patients before VAD insertion in an attempt to identify potential risk factors to patient survival in patients bridged to cardiac transplantation on Thoratec VADs. Preoperative BUN was identified as a marker of multi-organ pathophysiology that is of value in assessing bridge to transplant patients. In this study, pre-VAD BUN was significantly elevated in the nonsurvivors.

Golding, Crouch, et al. (1992) conducted an analysis of several laboratory values and also found preoperative BUN to have a predictive effect on survival. Both BUN and creatinine levels were significant factors affecting the ability to wean patients from the VAD ($p = .05$). Farrar, Lawson, et al. (1990) also found BUN to be significant for poor post-VAD implant survival. In contrast, Lick et al. (1993) found no correlation between preoperative BUN level and survival.

Total Bilirubin. In a study by Farrar and Thoratec Principal Investigators (1994) of 186 patients bridged to cardiac transplantation on Thoratec VADs, predevice total bilirubin levels were generally higher in the patients who did not survive to transplantation, however this level did not reach statistical significance. In those patients who were transplanted, higher total bilirubin levels neared statistical significance (p = .07) for increased risk of death following transplantation. Ashton et al. (1996) reported that at the time of transplantation, patients supported less than 30 days on VADs had a significantly elevated bilirubin level compared with patients supported for longer periods of time. Yet, elevated total bilirubin was not a significant risk factor for death in another study by Pennington, Farrar, et al. (1993).

Hematologic Factors. Pennington, McBride, Peigh, et al. (1994) reported predevice white blood count and platelet count to be statistically significant between the survivors and nonsurvivors of VAD support, regardless of whether or not the patient was transplanted. Swartz et al. (1994) also reported white blood cell count, as an indicator of infection, to be a statistically significant predictor of mortality in univariate analysis.

Blood Type. Significant risk factors for death include recipient and donor blood group other than type O (Bourge et al., 1993). Nakatani, Aida, Frazier, and Macris (1989) found that type O patients had a better survival rate than type A or B patients, although this was not statistically significant. Type A and B patients who received ABO identical hearts had better absolute graft survival rates than those transplanted with nonidentical ABO hearts. Once again this difference did not reach statistical significance. Patients with the type B antigen had significantly lower graft survival rates than type O patients and survived shorter periods than those without the type B antigen. Swartz et al. (1994) studied patients bridged to transplant on VADs and reported that patients with blood type O were more likely to require longer periods of mechanical support and therefore had a higher incidence of complications or death while being supported on these devices.

Reason for VAD Insertion. A retrospective study of predictors of weaning and survival post-VAD implant in 79 patients was conducted by Golding, Crouch, et al. (1992). They concluded that no differences existed between patients supported on VADs to wean from cardiopulmonary bypass or to treat ongoing cardiogenic shock or cardiac arrest. In contrast, Saperstein, Pae, Aufiero, Boehmer, and Pierce (1995) found that patients with acute myocardial infarction had a higher risk of death while being supported with LVADs than did chronically ill recipients. Massad et al. (1996) also found that patients who required LVAD insertion as a bridge to cardiac transplantation were more likely to have an ischemic event than those who did not require device support.

Other variables including body surface area (BSA), presence of other systemic disease, preoperative and postoperative ejection fraction, and New York Heart Association functional class have little relationship to predicting who will require postoperative VAD support or the prognosis of hospital survivors (Curtis, et al., 1990; Pennington, Merjavy, et al., 1985). Swartz et al. (1994) found that presence of an intra-aortic balloon pump was a statistically significant predictor of mortality in univariate analysis.

Device-Related Risk Factors

Type of VAD. A retrospective study of predictors of weaning and survival post-VAD implant in 79 patients conducted by Golding, Crouch, et al. (1992) found that although patients receiving biventricular support fared much worse, the difference in survival between patients supported on right ventricular assist devices (RVADS), left ventricular assist devices (LVADS), or biventricular assist devices (BIVADS) was not significant. Patients supported with biventricular assist devices exhibited a higher incidence of embolic events and hepatic insufficiency, however only the number of cerebrovascular accidents was significantly higher in the BIVAD group (Golding, Crouch, et al., 1992).

In a study of several preoperative variables evaluated with respect to survival post-VAD implant, Killen et al. (1991) and Farrar, Hill, Pennington et al. (1997) reported no significant difference in survival dependent on type of VAD used (LVAD, RVAD, or BIVAD). Miller, Pae, and Pierce (1990a) reported that the overall hospital discharge rate was not dependent on the type of support used, nor was there any significant difference if the patient was supported on a pneumatic versus a centrifugal device. Pennington, Reedy, et al. (1991) also reported no difference in incidence of complications with univentricular versus biventricular support with the Thoratec VAD.

Oaks, Pae, et al. (1991) found a significant difference in outcome dependent on the type of VAD used, with the best results occurring with the univentricular device and the least favourable results with the TAH. Magovern (1993) reported no significant influence on survival by type of assist, however Pae, Miller, Matthews, et al. (1992) found that hospital discharge rates were significantly lower in patients receiving biventricular support versus left or right sided support individually. In a study by Pennington, McBride, Peigh, et al. (1994), the best survival rates were found in patients requiring only left ventricular support.

Length of VAD Support. Magovern (1993) reported no significant influence on survival by length of VAD assist. The current overall experience no longer supports the previous trend of improved survival with shorter periods of mechanical support, but that extended mechanical bridging has a positive rather than a negative impact on long-term survival after cardiac transplantation (Oaks, Pae, et al., 1991; Frazier, Macris, et al., 1994). Extended LVAD support provides the potential for pretransplant rehabilitation by allowing the patient to become ambulatory, improve muscle tone, muscle mass, and nutritional status prior to transplantation (Nishimura, Radovancevic, Odegaard, Myers, Springer, & Frazier, 1996). Ashton et al. (1996) reported that patients undergoing cardiac transplantation who were supported on LVADs for less than 30 days were three times more likely to die in the perioperative period than those supported for greater than 30 days. These findings suggest that patients supported for longer periods of time have increased functional recovery leading to increased posttransplant survival. Contrary to the previous findings, Farrar, Hill, and the Thoratec VAD Principal Investigators (1994) found that the survival rate after transplantation does not appear to be related to the duration of support, and is comparable to that of conventional cardiac transplantation for both short and long-term assistance.

Complications of VAD Use

Complications with VAD use as a bridge to transplantation also have a significant relationship to poor outcomes posttransplant. Complications occur frequently with these devices, with the incidence reported at 78% (Bolman, Cox, et al., 1989). The highest risk of death occurs within the first month after transplantation. In the conventional cardiac transplant population, the three most common causes of death posttransplant are infection, acute rejection, and early graft failure (Bourge et al., 1993). Bleeding, renal failure, and infection are the most important indicators of early hospital death after cardiac transplantation in the bridged population (Pae, Miller, & Pierce, 1989; Korfer et al., 1995).

According to Pae (1993) and Pierce, Gray, McBride, and Frazier (1989), bleeding, DIC, renal and biventricular failure, cyanosis secondary to an unrecognized patent foramen ovale, inadequate cardiac output, and inlet cannula obstruction leading to low cardiac output were associated with the inability to wean a patient from mechanical support. Bleeding, neurologic events, and biventricular and renal failure had a significant negative effect on future cardiac transplantation.

Univariate analysis conducted by Miller, Pae, and Pierce (1990a) indicated that persistent biventricular failure, infection, inadequate cardiac output, and cannula obstruction accurately predicted the inability to wean a patient from support. The presence of renal failure, biventricular failure, cannula obstruction, decreased cardiac output, DIC, and cyanosis had a negative impact on hospital discharge and survival. Pennington, McBride, Peigh, et al. (1994) reported infection, renal failure, and respiratory failure to be significant predictors of nonsurvival, whereas mechanical failure, hemolysis, and thromboembolism were not.

Bleeding. A major negative determinant of posttransplant survival following VAD insertion is severe postoperative bleeding which requires massive transfusion of blood products (Golding, Crouch, et al., 1992). Patients supported on BIVADs were found to require more blood products, but this was not statistically significant. Reexploration of the chest was warranted in 22% to 73% of patients (Farrar, Lawson, et al., 1990; Pennington, McBride, Kanter, Swartz, et al., 1988; Kanter, McBride, et al., 1988; Killen et al., 1991; Magovern, 1993; Marks et al., 1992; Parascandola et al., 1988; Pennington, Bernhard, et al., 1985; Golding, Jacobs, et al., 1982; Pennington, McBride, Swartz, et al., 1989; Portner, Oyer, et al., 1989; Pennington, Merjavy, et al., 1985; Zumbro et al., 1987).

Postoperative bleeding is known to be a result of the length of the operative procedure, associated coagulation defects, and multiple cannulation sites in the heart and great vessels, rather than use of the device itself. However, bleeding complications occur more frequently with the centrifugal pumps than with the pneumatic devices (Pennington, Farrar, et al., 1993). Uncontrolled bleeding disorders may lead to pulmonary insufficiency and multi-organ failure. Coagulopathy secondary to frequent blood transfusion leads to pulmonary hypertension and results in decreased VAD flow.

Hemolysis. Hemolysis should be minimized by prompt institution of mechanical support and selection of appropriately sized cannulae for arterial return (Golding, Stewart, et al., 1988; Pennington, Bernhard, et al., 1985). A moderate amount of hemolysis will occur in patients who are supported on devices long-term (Gray, Ganzel, Mavroudis, & Slater, 1989).

Thromboembolism. Another frequent complication of mechanical circulatory support is thromboembolism. Approximately 12% of VAD patients suffer a neurologic event related to an embolic process (Pae, Miller, & Pierce, 1989). Turbulent flow, platelet damage, thrombogenicity, and design of the device put patients at risk for thrombus formation (Henker, 1991; Didisheim et al., 1989). Large synthetic blood-contacting surfaces combined with low flow rates may also predispose patients to clotting which compromises the function of the device or produces thromboembolic complications in other organs (DeVries, 1984). Icenogle et al. (1989) reported development of thrombi in the Symbion VAD in 78% of patients. The incidence of thrombus formation found with the Thoratec VAD was 17% with the incidence of embolization 4% to 8% (Termuhlen et al., 1989). Thrombi were related to inadequate anticoagulation, interrupted VAD flow, or sepsis, but not to duration of support. Adamson et al. (1989) reported an incidence of cerebrovascular accident of 21% post-VAD insertion. Incidence of thrombosis was decreased with the use of ventricular drainage cannulae to avoid ventricular stasis and prevent clotting and stroke.

Renal Failure. Renal pathophysiology in cardiac assist device patients is related to decreased cardiac output and hemoglobinuria (Henker, 1991). Effects of cardiopulmonary bypass, hemodilution, hypothermia, prolonged aortic cross-clamp time, high transfusion requirements, and low nonpulsatile flow add to reduced renal perfusion (Quaal, 1991; DeVries, 1984; Reedy, Ruzevich, et al., 1990). VADs damage red blood cells and release hemoglobin into the plasma. Plasma-free hemoglobin is nephrotoxic and results in compromised renal function. Plasma-free hemoglobin and lactate dehydrogenase levels are monitored to determine the amount of hemolysis that is occurring (Henker, 1991). In studies of patients bridged to cardiac transplant, Drinkwater and Laks (1988) and Kanter, Swartz, et al. (1987) found the development of renal failure to be the most ominous prognostic indicator. Pierce, Hershon, Kormos, Dembitsky, and Noon (1993) found that only 33% of patients with renal failure supported on mechnanical devices survived to transplantation. Of 79 patients who received ventricular support for postcardiotomy cardiogenic shock, 37 patients (46.8%) demonstrated varying degrees of renal insufficiency. Only 3 patients (8.1%) with renal dysfunction survived despite early and aggressive management. This poor survival rate was statistically significant when compared to the overall group survival (Golding, Crouch, et al., 1992). When patients were supported with LVADs for extended periods of time, renal function normalized in two-thirds of patients (Burnett, Duncan, Frazier, Sweeney, Vega, & Radovancevic, 1993).

Infection. Infection is a major risk factor of prosthetic hearts, especially in patients who survive to cardiac transplantation and are chronically immunosuppressed. Greater infection related morbidity and mortality occur with the orthotopic approach as compared to the heterotopic approach (Hill, 1989; Griffith, Kormos, Hardesty, & Armitage, 1988). An infection rate of 36% has been reported by Griffith, Kormos, et al. (1988) in patients bridged to transplant on TAHs. Infection has also been significantly associated with the use of pneumatic devices due to the increased number of days of support afforded by these types of devices (Pae, Miller, Matthews, et al., 1992; McBride, Ruzevich, et al., 1987; Pennington, McBride, Miller, et al., 1994; Shinn, Abou-Awdi, et al., 1993; Ashton, et al., 1996; Masters et al., 1996). However, Prendergast et al. (1996) suggest that transplantation should not be delayed in patients with infected VADs, as acceptable results can be achieved in the presence of VAD infections from bacteria or fungus.

Pneumonia, mediastinitis, and device-related infections are the most common septic complications. The presence of indwelling devices, chronic debilitation due to heart failure, the presence of cavities and voids created by the devices, blood-borne pathogens flowing turbulently through the pumps, adherence of certain bacteria to polyurethane surfaces, and sequestration of organisms from the usual antibody and phagocytic responses, are reasons for increased susceptibility of these patients to infection (Didisheim et al., 1989; Lonchyna et al., 1992).

Multi-organ Failure. Multi-organ failure is a principle cause of death in patients placed on VADs who become noncandidates for transplantation (Hill, 1989). At the time of device implantation, it is very difficult to know if secondary organ dysfunction is reversible. Risk factors for multi-organ failure include ECMO or mixed devices, a long bypass time in postcardiotomy patients, previous or multiple operations, and prolonged low cardiac output syndrome (Pierce, Hershon, et al., 1993). Patients with multiple organ failure must be supported with long-term devices to provide sufficient time to allow for reversal of end-organ dysfunction (Burnett et al., 1993).

Magovern (1993) reported no significant influence on survival by the complications of VAD support when studying the use of the Biopump centrifugal VAD. Survival improved significantly when analyzed by operative era. This improvement was attributed to increased physician and perfusionist expertise, more aggressive institution of VAD support, and improved patient selection.

Donor-Related Variables

Several reports indicate that increased donor ischemic time (greater than 4 hours) will result in a higher early mortality following cardiac transplantation (Fragomeni & Kaye, 1988; English, Spratt, Wallwork, Cory-Pearce, & Wheeldon, 1984; Wahlers et al., 1991). A study conducted on 39 survivors and nonsurvivors of transplantation by Wahlers et al. (1991) found that the duration of donor catecholamine support was significantly longer for transplant recipients who died in the early postoperative period when compared to the survivors. Older donor age and donor blood group other than type O were also predictive of poorer survival rates in posttransplant patients bridged on VADs (Bourge et al., 1993; Wahlers et al., 1991).

Summary

Ventricular assist devices provide circulatory support to patients who would have otherwise died. Several devices are available for use including centrifugal pumps, ECMO, the Hemopump, pneumatic devices, implantable pumps, and the TAH. However each device is limited by specific associated risks and complications. Pre-VAD, device-related, and donor-related risk factors in addition to complications of VAD support must be assessed and patients carefully selected as candidates for bridging to transplant in order to minimize these risk factors to ensure that precious donor organs are allocated to those patients who are likely to benefit from transplantation.

CHAPTER THREE

Method

Numerous studies conducted on the use of ventricular assist devices (VADs) as a bridge to cardiac transplantation have produced contradictory findings. Certain patient variables are statistically significant in some samples for outcomes post-bridging to cardiac transplantation, while they are nonsignificant in others. A study of preoperative risk factors and analysis of VAD selection and application to posttransplant outcomes was conducted in order to provide the basis by which to improve patient selection, provide comprehensive care to the bridged patient, and ultimately improve long-term survival rates after cardiac transplantation. In view of the decreasing availability of donor organs, it was important to critically analyze the outcomes obtained with VADs to ascertain their effectiveness and to determine if the continued use of precious donor organs in patients bridged to transplant on these devices was justified (Kanter, McBride, et al., 1988).

The purpose of this study was to examine factors present in adults bridged to cardiac transplantation with VADs that impacted posttransplant outcomes. The following questions were addressed:

a. What were the characteristics of patients who had a VAD inserted as a bridge to cardiac transplantation?

b. What were the outcomes of patients bridged to cardiac transplantation on VADs?

c. What factors affected posttransplant outcomes in patients bridged to cardiac transplantation on VADs?

The results obtained were analyzed and provide a description of the patients bridged to cardiac transplantation and information regarding the effectiveness of the VADs used at the University of Alberta Hospital as bridging devices. The findings provide a Canadian perspective to the existing knowledge in this field and allow comparisons to be made with American and International data. In addition, the data from this patient population verified in some respects, and contradicted in others, existing research findings which will lead to further research questions and study, and ultimately improve the care of the bridged patient.

Design

A descriptive, retrospective, correlational design was used to examine the relationships among demographics, pre-VAD implant data, laboratory values, hemodynamic parameters, surgical data, device and donor-related variables, complications of VAD support, and patient outcomes.

Study Population

The study population consisted of all adults, 18 years and older, placed on VADs (Bio-Medicus, Hemopump, Extracorporeal membrane oxygenation) with the intent to bridge to cardiac transplantation. All patients since the inception of the cardiac transplant program at the University of Alberta Hospital in 1985 to the present time were included in the study.

Data Collection Procedure

A retrospective review of all inpatient hospital charts and transplant outpatient charts was conducted. Data on study variables were collected from the patient's chart through the period of VAD insertion and cardiac transplantation to the present, or until the time that death occurred. Demographic data, preimplant data, laboratory values, hemodynamic data, surgical data, device data, complications of VAD support, and patient outcome data were obtained to identify variables that were predictive of posttransplant survival. Specific donor-related variables identified in the literature as having a negative impact on posttransplant survival were also obtained.

Patient demographics were collected from the admission data base, patient history, and physical assessment records. Pre-VAD implant laboratory values, hemodynamic data, and duration of cardiogenic shock, and inotropic support were obtained from cardiac catheterization, operative, and graphic records. Post-VAD insertion daily laboratory values were collected while the patient was in the intensive care unit, at the time of hospital discharge, and at the present time. If the patient was deceased, the data was obtained as close to the time of death as possible.

Hemodynamic data was collected on a daily basis while the patient was in the intensive care unit, with a 24 hour mean (± standard deviation) calculated for each parameter. Heart rate and blood pressure were also documented on the hospital discharge day and at the most recent transplant clinic visit. Additional data were obtained from the operative record, daily graphic sheets, progress notes, and nursing notes.

Patient outcomes were documented as mortality, morbidity, ability to wean from the VAD, and functional recovery. Mortality was assessed by survival to transplant, length of posttransplant survival in days, survival to hospital discharge, and survival following hospital discharge. Morbidity was assessed by the presence/absence of intraoperative and posttransplant complications and the type of complications that occurred. The number of rejection episodes and grade (Appendix A), the number and type of major systemic infections, and the number of hospital readmissions and reason for admission were identified. Those patients who were not transplanted were classified as weaned/unable to wean from VAD. Functional recovery was assessed by ability of the patient to return to work posttransplant or to perform lifestyle activities that they performed prior to illness. New York Heart Association functional class (Appendix B) was documented for each patient.

Data Analysis

Descriptive statistics including the mean, standard deviation, and range were calculated with respect to each variable to depict the characteristics of patients bridged to cardiac transplant on VADs. Correlation coefficients were calculated to describe the relationships among specified study variables. Variables with statistically significant correlation coefficients were subjected to multiple regression analyses to identify trends in variables that may be predictive of posttransplant outcomes. Chi-square analyses and Fischer's exact test were conducted on nominal data to determine if significant group differences existed on patient outcomes. Missing data were handled by coding the data as such, and running the analyses using the missing data option in SPSS (Version 6.1). The level of significance was set at $p < .05$.

Ethical Considerations

Ethical clearance was obtained from the Faculty of Nursing and Special Services and Research Committee, University of Alberta Hospital prior to initiation of data collection. All patient information was kept strictly confidential with patients identified only by hospital identification number. There was no risk of harm to patients because the study was conducted retrospectively, however future patients being considered for bridge to transplant procedures may benefit from the results of this study. Records were accessed through the Medical Records Department, University of Alberta Hospital after ethical approval from the institution had been obtained.

CHAPTER FOUR

Findings

The purpose of this study was to examine factors that affected posttransplant outcomes in adults bridged to cardiac transplantation on ventricular assist devices (VADs). This study addressed the following questions:

1. What were the characteristics of patients who had a VAD inserted as a bridge to cardiac transplantation?
2. What were the outcomes of patients bridged to cardiac transplantation on VADs?
3. What factors affected the posttransplant outcomes in patients bridged to cardiac transplantation on VADs?

Descriptive statistics were used to depict the characteristics of the subjects. Correlation coefficients and multiple regression analyses were used to identify relationships among specified variables and patient outcomes. Chi-square analyses and Fischer's exact test were used with nominal data to determine if significant group differences existed on patient outcomes.

Description of the Subjects

Of the 85 patients who were placed on a VAD at the University of Alberta Hospital from 1985 to the present time, 65 (76%) were placed on the devices with the intent to bridge to cardiac recovery, and 20 (24%) with the intent to bridge to cardiac transplantation. The twenty patients who were bridged to cardiac transplantation were the subjects of this study. Of these 20 patients, there were 16 males (80%) and 4 females (20%). Average age of the patients was 48.6 years (SD = 9.53, range 20 to 62 years) with an average body surface area of 1.89m^2 (SD = .17, range 1.48 to 2.20m^2). Coronary artery disease was diagnosed in 19 patients (95%), and dilated cardiomyopathy in 1 patient (5%). Mean ejection fraction (EF) of the patients was 30.19% (SD = 17.83, range 5 to 74%). Reasons for VAD insertion included cardiogenic shock post-myocardial infarction (MI) (*N* = 7, *f* = 35%), post-cardiotomy (*N* = 11, *f* = 55%), and cardiac arrest (*N* = 2, *f* = 10%). Nine patients (45%) had no previous cardiac surgical procedure, while 11 patients (55%) had a history of cardiac surgery. Eight patients (40%) had undergone 1 cardiac operative procedure, 2 patients (10%) had 2 previous cardiac surgeries, and 1 patient (5%) had 3 previous cardiac surgical procedures. Of the patients who had undergone previous surgery, 8 patients (40%) had coronary artery bypass grafting (CABG), 1 patient (5%) had CABG and left ventricular aneurysmectomy, 1 patient (5%) had a cardiotomy with no CABG due to the inability to find suitable vessels for grafting (the same patient who had 2 previous cardiac surgeries), and 1 patient (5%) had CABG with repair of the sinus of valsalva. The mean cardiopulmonary bypass time (CPB) time for these 11 patients was 212.45 minutes (*SD* = 130.68, range 65 to 525 minutes).

Duration of cardiogenic shock for all patients (time of cardiac insult to time of transplant or death) averaged 40.75 hours (*SD* = 24.59, range 6.83 to 104.02 hours) while mean number of hours on the VAD (from time of insertion to time of transplant or death) was 40.46 hours (*SD* = 23.72, range 9.88 to 104.02 hours). An intra-aortic balloon pump (IABP) was used for the maintenance of pulsatile flow in 17 patients (85%), while the same number of patients experienced a cardiac arrest prior to or during the period of VAD use. Of the VADs used, a left ventricular assist device (LVAD) was used to support 8 patients (40%), a biventricular assist device (BIVAD) was used for 3 patients (15%), and extracorporeal membrane oxygenation (ECMO) was used for 9 patients (45%). Fifty percent of the patients (*N* = 10) were supported by a Biomedicus centrifugal pump, 5% (*N* = 1) by a Hemopump, and 45% (*N* = 9) by a CPS Bard extracorporeal system.

Lifestyle factors assessed showed that 16 patients (80%) had a history of smoking, while 5 patients (25%) had a history of alcohol abuse (> 2 drinks/day). Viral studies done during the transplant assessment showed that 14 patients (70%) were cytomegalovirus (CMV) positive, while 3 patients (15%) continued to test negative for the virus. Fourteen patients (70%) had been previously exposed to and tested positive for Epstein-Barr virus (EBV), while 1 patient (5%) was EBV negative. Documented patient blood group showed that 6 patients (30%) were O positive, 9 patients (45%) were A positive, 1 patient (5%) was A negative, and 4 patients (20%) were B positive.

Of the 20 patients placed on VADs, 7 (35%) survived to cardiac transplantation, and 1 patient (5%) improved significantly to allow weaning of the VAD without cardiac transplantation. Three patients (15%) were removed from the transplant list due to neurological complications including brain death; 1 patient (5%) was delisted due to sepsis, with subsequent withdrawal of VAD support; 1 patient (5%) was delisted due to renal failure; and 1 patient (5%) was delisted due to uncontrollable bleeding. One patient (5%) suffered from a combination of sepsis and uncontrollable bleeding which lead to withdrawal of VAD support; 1 patient (5%) had neurological and septic complications; and 1 other (5%) had neurologic deficits in addition to uncontrollable bleeding. Two patients (10%) suffered from renal failure and bleeding disorders; while 1 patient (5%) was delisted due to a combination of neurological deficits, bleeding disorders, and renal failure.

Cause of death in those patients removed from the transplant list was ongoing cardiogenic shock in addition to the aforementioned complications. Table 4.0 displays patient demographics, VAD data, and patient outcomes.

Table 4.0

Characteristics and Outcomes of 20 Candidates Bridged to Cardiac Transplantation on VADs

Pt	Age	Sex	BSA	Dx	OR	VAD	Hrs of Support	IABP	Tx	Status	Cause of Death
1	20	M	1.84	DC	N	L	104.02	N	Y	Alive	---
2	41	F	1.61	CAD	Y	BI	47.20	Y	N	Dead	B/S/C
3	58	F	1.76	CAD	Y	EC	9.88	N	N	Dead	B/C
4	55	M	2.00	CAD	N	EC	22.42	Y	Y	Alive	---
5	46	M	2.04	CAD	Y	L	35.77	Y	Y	Dead	B/C/G
6	53	F	1.48	CAD	Y	EC	21.72	Y	Y	Alive	---
7	62	M	1.90	CAD	Y	L	29.82	Y	N	Dead	C
8	48	M	1.90	CAD	N	EC	47.57	N	N	Dead	N/C
9	47	M	1.86	CAD	Y	L	75.57	Y	N	Alive	---
10	47	M	2.00	CAD	Y	L	31.08	Y	N	Dead	N/C
11	49	M	1.80	CAD	N	EC	44.98	Y	N	Dead	N/B/R/C
12	45	M	1.90	CAD	N	EC	65.37	Y	Y	Alive	---
13	55	M	2.02	CAD	N	EC	48.27	Y	Y	Dead	S/MOF
14	58	M	1.67	CAD	Y	L	66.00	Y	N	Dead	C
15	50	M	1.90	CAD	Y	BI	37.03	Y	N	Dead	R/B/C
16	40	M	1.92	CAD	N	EC	46.50	N	N	Dead	R/C
17	49	M	2.10	CAD	Y	L	21.98	Y	N	Dead	N/B/C
18	38	M	2.20	CAD	N	L	10.17	Y	N	Dead	N/C
19	62	M	2.00	CAD	N	EC	30.25	Y	N	Dead	R/B/C
20	49	F	1.86	CAD	Y	BI	13.67	Y	Y	Dead	AAA

Note. Pt = Patient; Age in years; M = Male, F = Female; BSA = Body surface area in m^2; Dx = Diagnosis, DC = Dilated cardiomyopathy, CAD = Coronary artery disease, OR = Previous cardiac surgery, Y = Yes, N = No; VAD = Type of VAD, L = Left ventricular assist device, BI = Biventricular assist device, EC = Extracorporeal membrane oxygenation; Hrs = Hours; IABP = Intra-aortic balloon pump; Tx = Transplant; B = Bleeding; S = Sepsis; C = Cardiogenic shock; G = Graft failure; N = Neurologic deficit; R = Renal failure; MOF = Multiorgan failure; AAA = Abdominal aortic aneurysm rupture.

Donor-Related Variables

Over the course of this study, 7 organ donors were identified and 7 cardiac transplants performed. Of these 7 donors, 5 were male (71%), and 2 (29%) were female. Six donors (86%) were blood type O positive, while 1 donor (14%) was A positive. In addition, 6 donors (86%) were (CMV) positive while 1 donor (14%) was CMV negative. Donor age averaged 31.71 years (SD = 12.15, range 16 to 46 years) and mean donor ischemic time (DIT) was 260.86 minutes (SD = 126.50 minutes, range 94 to 424 minutes). Donors who were on inotropes were identified, with 4 donors on > 10ug/kg/min of Dopamine, and all donors (N = 7) on Norepinephrine at ≤ .2ug/kg/min (Table 4.1). No donors were supported with the use of Epinephrine.

Table 4.1

Donor Variables

	N	**μ**	**SD**	**Range**
Donor Age	7	31.710	12.15	16.00- 46.00
DIT	7	260.860	126.50	94.00-424.00
Dopamine	7	10.430	6.41	3.50- 20.00
Norepinephrine	7	.008	.02	.00- .06

Note. Donor age in years; DIT = Donor ischemic time in minutes; Dopamine and Norepinephrine measured in ug/kg/min.

Pre-VAD Implant Status

Several variables were measured on the 20 study subjects to determine the patients' status prior to VAD insertion. These variables included measures of neurological function, hemodynamic status, inotropic support, cardiac rhythm, respiratory status, renal function, liver function, bleeding status, and infectious complications. Patients considered for VAD implantation were those who remained in cardiogenic shock despite the initiation of maximal inotropic support and the institution of an IABP. Neurologic and hemodynamic data of patients prior to institution of ventricular assist support is shown in Table 4.2. Neurologic function was essentially normal in all patients who were considered for support. Hemodynamic status of the patients was measured prior to the initiation of cardiac surgery in those patients who had surgery, while those patients who presented in cardiogenic shock post-MI had their hemodynamic parameters measured in the cardiac catheterization laboratory.

Table 4.2

Pre-VAD Implant Neurologic and Hemodynamic Status

	N	μ	SD	Range
GCS	20	.99	.05	.80- 1.00
HR	20	86.66	23.97	54.00- 144.35
HRSE	20	5.99	9.53	.00- 35.20
SBP	19	108.99	30.23	60.00- 202.00
SBPSE	19	6.58	8.41	.00- 26.12
DBP	19	65.94	8.98	22.00- 122.00
DBPSE	19	5.01	6.78	.00- 23.46
MAP	20	79.75	22.26	47.00- 148.67
MAPSE	20	5.07	6.94	.00- 21.35
CO	9	5.04	1.46	3.00- 7.88
COSE	9	.08	.25	.00- .75
CI	9	2.66	.55	1.86- 3.58
CISE	9	.05	.14	.00- .43
PVRI	9	274.30	164.98	86.00- 560.98
PVRSE	9	10.78	32.33	.00- 96.99
SVRI	9	1947.06	734.57	992.30-3268.82
SVRSE	9	26.07	78.21	.00- 234.62

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 10 or 15 dependent on whether or not the patient is intubated); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg; CO = Cardiac output in L/min; CI = Cardiac index in L/min/m^2; PVRI = Pulmonary vascular resistance index in dynes/sec^2/cm^{-5}/m^2; PVRSE = PVRI standard error; SVRI = Systemic vascular resistance index in dynes/sec^2/cm^{-5}/m^2; SVRSE = SVRI standard error.

Maximal inotropic support was recorded as the number of inotropes that were infused, the dose of the drug and the range, and the length of time that the medication was infused (Table 4.3). Data is missing for one patient who was admitted from an outside hospital directly to the cardiac catheterization lab with no documentation of type of inotropes, doses, or length of infusions noted.

Prior to VAD implantation, patients were on a mean of 1.25 inotropes (N = 20, SD = 1.37, range 0 to 4), 13 patients (65%) were on Dopamine ≤ 5ug/kg/min, 2 patients (10%) were on Dopamine > 5 < 10ug/kg/min, and 4 patients (20%) were on Dopamine ≥ 10ug/kg/min. Fourteen patients (70%) were on Dobutamine infusions of ≤ 10ug/kg/min, while 5 patients (25%) were on higher doses (up to 21.80ug/kg/min). Of the patients on Epinephrine infusions (N = 3), all were on ≤ .2ug/kg/min.

Seventeen patients (85%) were on Norepinephrine doses of ≤ .2ug/kg/min, and 2 patients (10%) were on doses up to .300 ug/kg/min. All patients were on Amrinone at ≤ 10ug/kg/min. Eighteen patients (90%) were on Nitroglycerine (NTG) at ≤ 2.5ug/kg/min, while 1 patient (5%) was on NTG at > 2.5ug/kg/min. All patients (N = 19) were on ≤ 2.5ug/kg/min of Sodium Nitroprusside (SNP), ≤ 10ug/min of

Isoproterenol, ≤ 2mg/min of Lidocaine, ≤ 2mg/min of Procainamide, ≤ .05ug/kg/min of Neosynephrine, and ≤ 2mg/min of Bretylium.

Table 4.3

Pre-VAD Implant Inotropic Support

	N	μ	SD	Range
# Inotropes	20	1.250	1.370	.000- 4.000
Dopamine	19	3.950	6.030	.000-17.220
DopHr	18	4.330	7.850	.000-24.000
DopLo	19	1.550	3.740	.000-15.000
DopHi	19	5.270	8.000	.000-20.000
Dobutamine	19	4.500	6.990	.000-21.800
DobHr	19	4.580	7.710	.000-24.000
DobLo	19	2.500	5.710	.000-21.800
DobHi	19	5.020	7.780	.000-21.800
Epinephrine	19	.006	.016	.000- .062
EpiHr	19	.530	1.350	.000- 5.000
EpiLo	19	.000	.000	-------
EpiHi	19	.010	.029	.000- .107
Norepinephrine	19	.031	.021	.000- .300
NorepiHr	19	.790	2.420	.000- 9.000
NorepiLo	19	.016	.069	.000- .300
NorepiHi	19	.031	.093	.000- .300
Amrinone	19	.000	.000	-------
AmrinHr	19	.000	.000	-------
AmrinLo	19	.000	.000	-------
AmrinHi	19	.000	.000	-------
NTG	19	.360	1.260	.000- 5.500
NTGHr	19	3.320	7.190	.000-24.000
NTGLo	19	.020	.060	.000- .270
NTGHi	19	.400	1.350	.000- 5.900
SNP	19	.040	.170	.000- .740
SNPHr	19	1.260	5.510	.000-24.000
SNPLo	19	.040	.160	.000- .700
SNPHi	19	.050	.230	.000- 1.000
Isoproterenol*	19	.000	.000	-------
IsoproHr	19	.000	.000	-------
IsoproLo	19	.000	.000	-------
IsoproHi	19	.000	.000	-------
Lidocaine**	19	.000	.000	-------
LidoHr	19	.000	.000	-------
LidoLo	19	.000	.000	-------
LidoHi	19	.000	.000	-------
Procainamide**	19	.000	.000	-------
ProcanHr	19	.000	.000	-------
ProcanLo	19	.000	.000	-------
ProcanHi	19	.000	.000	-------
Neosynephrine	19	.000	.000	-------
NeosynHr	19	.000	.000	-------
NeosynLo	19	.000	.000	-------
NeosynHi	19	.000	.000	-------
Bretylium**	19	.000	.000	-------
BretylHr	19	.000	.000	-------
BretylLo	19	.000	.000	-------
BretylHi	19	.000	.000	-------

Note. # inotropes = Number of inotropes; All drugs in ug/kg/min unless otherwise specified. Dop = Dopamine; Hr = Number of hours infused; Lo = Lower range; Hi = Higher range; Dob = Dobutamine; Epi = Epinephrine; Norepi = Norepinephrine; Amrin = Amrinone; NTG = Nitroglycerine; SNP = Sodium Nitroprusside; Lido = Lidocaine; Procan = Procainamide; Neosyn = Neosynephrine; Bretyl = Bretylium; * = ug/min; ** = mg/min.

Rhythm strips and 12 lead electrocardiograms (ECGs) were evaluated when available, to determine the patients' cardiac rhythm prior to VAD implantation. Most patients (N = 17) presented with one predominant rhythm, however others (N = 3) exhibited 2 or more different rhythms during this period of time. Normal sinus rhythm (NSR) was the most common, with 50% of patients (N = 10) in that group. Five percent of patients (N = 1) had sinus bradycardia, and 25% (N = 5) had sinus tachycardia. Two patients (10%) had sinus tachycardia with premature atrial contractions (PACs) (N = 1) or premature ventricular contractions (PVCs) (N = 1). Two patients (10%) presented with atrioventricular heart block, while one (5%) developed a supraventricular tachycardia (SVT). Temporary pacing was required in 3 patients (15%).

On evaluation of the 12 lead ECG, 6 patients (30%) had evidence of anterior ischemia or infarction; 3 patients (15%) had evidence of inferior ischemia or infarction; and 1 patient (5%) had left ventricular hypertrophy. ST segment depression (N = 2, f = 10%), ST elevation (N = 4, f =20%), and T wave changes (N = 9, f = 45%) were also seen.

Cardiac enzymes were also recorded, if available, to further corroborate the diagnosis of myocardial infarction. Lactic dehydrogenase (LDH) and creatine kinase (CK) [± fractionated myocardial band (CKMB)] were monitored prior to VAD implementation (Table 4.4). Mean LDH, CK, CKMB, and fractionated CKMB (M = 725.50 U/Litre, 1003.64 U/Litre, 158.12 U/Litre, and .07 U/Litre respectively) were markedly elevated, identifying significant myocardial ischemia or infarction prior to VAD implantation.

Table 4.4

Pre-VAD Implant Cardiac Enzymes

	N	**μ**	**SD**	**Range**
LDH	4	725.50	802.90	138.00-1908.00
CK	11	1003.64	1172.52	20.00-3332.00
CKMB	6	158.12	118.94	12.00- 333.00
FRCKMB	5	.07	.04	.03- .11

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase in U/L; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

Respiratory function of patients was monitored by serial measurements of FiO_2, PO_2, PEEP (positive end expiratory pressure), and number of days intubated. Mean FiO_2 was .49 with a resultant mean PO_2 of 81.46 mmHg. Average PEEP was +1.00 cmH_2O with the mean number of hours intubated equal to 3.60 (Table 4.5).

Table 4.5

Pre-VAD Implant Respiratory Parameters

	N	**μ**	**SD**	**Range**
FiO2	20	.49	.33	.21- 1.00
FiO2SE	20	.02	.05	.00- .31
PO2	20	81.46	26.29	54.00-157.00
PO2SE	13	4.65	10.66	.00- 36.06
PEEP	20	1.00	2.62	.00- 10.00
PEEPSE	20	.00	.00	-------
ETT	20	.15	.08	.00- 1.00

Note. FiO_2 = Fraction of inspired oxygen; SE = Standard error; PO_2 = Partial pressure of oxygen in mmHg; PEEP = Positive end expiratory pressure in cmH_2O; ETT = Number of days intubated.

Laboratory data such as creatinine, blood urea nitrogen (BUN) and total bilirubin, in addition to objective data such as urine output, were collected, if available, to evaluate renal and hepatic function during the pre-VAD implantation phase. Mean values of these variables were within expected ranges for their respective parameters (Table 4.6).

Table 4.6

Pre-VAD Implant Renal and Hepatic Function

	N	**μ**	**SD**	**Range**
Creatinine	18	112.83	43.36	56.00-226.00
BUN	16	6.95	4.59	3.00- 22.90
U/O	9	104.19	128.03	40.00-215.00
U/OSE	9	53.71	63.37	.00-173.84
TBili	6	11.17	5.23	4.00- 20.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Bleeding status of the patients was measured by a variety of different parameters. These included laboratory data, if available, such as hemoglobin (Hgb), hemocrit (Hct), PTINR (prothrombin time) (N = 17, 11 patients [55%] had a normal PTINR, while 6 patients [30%] had an elevated PTINR), PTT (partial thromboplastin time), platelet count, and activated clotting time (ACT); and objective data such as chest tube loss, and number of blood product transfusions (Table 4.7).

Data collected to determine the infection status of the patient prior to VAD implantation included white blood count (WBC), temperature, and number of positive cultures. Out of 5 patients who had cultures done prior to VAD implementation, no patients showed evidence of infection. Mean temperature and WBC were also within normal limits (Table 4.8).

Table 4.7

Pre-VAD Implant Hematological Factors

	N	μ	SD	Range
Hgb	19	130.95	21.48	79.00-158.00
Hct	20	.39	.06	.23- .48
PTT	17	68.07	42.91	24.60-150.00
Plt	19	231.16	71.15	91.00-356.00
CT Loss	20	2.78	12.42	.00- 55.56
CTSE	20	.50	2.24	.00- 10.00
ACT	2	492.84	143.07	391.67-594.00
ACTSE	2	31.77	44.93	.00- 63.54
PC	20	.50	1.57	.00- 6.00
FFP	20	.05	.22	.00- 1.00
PltTr	20	.30	1.34	.00- 6.00
Cryo	20	.00	.00	-------

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit in L/L; PTT = Partial thromboplastin time in seconds; Plt = Platelets in thousands/mm^3; CT Loss = Chest tube loss in mls/hr; CTSE = Chest tube loss standard error; ACT = Activated clotting time in seconds; ACTSE = Activated clotting time standard error; PC = Packed cells transfused in units; FFP = Fresh frozen plasma transfused in units; PltTr = Platelets transfused in units; Cryo = Cryoprecipitate transfused in units.

Table 4.8

Pre-VAD Implant Infection Status

	N	μ	SD	Range
WBC	20	12.00	6.90	6.10-37.10
TEMP	17	36.55	.65	35.50-37.90
TEMPSE	17	.21	.36	.00- .36

Note. WBC = White blood cell count 10^9/L; TEMP = Temperature in °C; TEMPSE = Temperature standard error.

Status at Time of VAD Insertion

All of the variables measured during the pre-VAD implementation phase were repeated on the day of VAD insertion to provide an accurate depiction of patient status at the time of initiation of VAD support. Only nineteen patients were included in this analysis. The other patient's day of VAD insertion was the same as the day of transplant, therefore the data are included in subsequent analysis. Neurologic and hemodynamic parameters are shown in Table 4.9.

On VAD implantation day, patients were on an average of 3.26 inotropes (N = 19, SD = 1.49, range 1 to 6). Forty-seven percent of patients (N = 9) were on Dopamine ≤ 5ug/kg/min; 26% of patients (N = 5) were on Dopamine > 5 < 10ug/kg/min; while 26% of patients (N = 5) were on Dopamine ≥ 10 ug/kg/min. Seventeen patients (89%) were on Dobutamine at ≤ 10ug/kg/min, while 2 patients (11%) remained on higher doses. Epinephrine doses were ≤ .2ug/kg/min for 14 patients (74%), and > .2ug/kg/min for 4 patients (21%). Ninety-five percent of patients (N = 18) were on ≤ .2ug/kg/min of Norepinephrine, ≤ 10ug/kg/min of Amrinone, and ≤ 2.5ug/kg/min of SNP. All patients (N = 19) were on ≤ 10ug/kg/min of Isoproterenol, ≤ 2mg/min of Procainamide, and ≤ 2mg/min of Bretylium. NTG was infused at ≤ 2.5ug/kg/min in 16 patients (84%), while Lidocaine was ≤ 2 mg/min in 15 patients (79%). Two patients (11%) with severe refractory hypotension were maintained on Neosynephrine ≥ .05ug/kg/min.

Table 4.9

Neurologic and Hemodynamic Status on VAD Implant Day

	N	μ	SD	Range
GCS	19	.66	.05	.20- 1.00
HR	19	112.79	19.20	70.50- 140.67
HRSE	19	11.86	7.58	1.15- 28.79
SBP	19	109.52	24.86	70.89- 161.13
SBPSE	19	14.49	8.36	3.87- 38.31
DBP	19	65.99	6.89	53.81- 83.18
DBPSE	19	9.43	5.72	3.52- 27.39
MAP	19	81.55	11.71	58.50- 100.58
MAPSE	19	10.95	7.36	2.99- 34.60
CO	8	5.47	1.11	3.90- 7.28
COSE	8	.79	.86	.00- 2.66
CI	8	2.78	.34	2.40- 3.35
CISE	8	.39	.40	.00- 1.24
PVRI	8	311.85	121.27	101.42- 483.79
PVRSE	8	107.75	106.07	.00- 328.23
SVRI	8	1896.05	389.96	1180.75-2465.00
SVRSE	8	237.21	224.06	.00- 698.95

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 10 or 15 dependent on whether or not the patient is intubated); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg; CO = cardiac output in L/min; CI = cardiac index in L/min/m^2; PVRI = Pulmonary vascular resistance index in dynes/sec^5/cm^{-5}/m^2; PVRSE = PVRI standard error; SVRI = Systemic vascular resistance index in dynes/sec^5/cm^{-5}/m^2; SVRSE = SVRI standard error.

Table 4.10

Inotropic Support on VAD Implant Day

	N	**μ**	**SD**	**Range**
# Inotropes	19	3.260	1.490	1.000- 6.000
Dopamine	19	6.470	5.550	.000-20.000
DopHr	19	7.320	7.310	.000-24.000
DopLo	19	3.990	5.900	.000-20.000
DopHi	19	7.310	6.020	.000-20.000
Dobutamine	19	3.090	6.430	.000-20.000
DobHr	19	2.950	6.920	.000-24.000
DobLo	19	2.340	6.230	.000-20.000
DobHi	19	3.400	6.880	.000-20.000
Epinephrine	19	.155	.272	.000- 1.160
EpiHr	19	5.050	7.260	.000-24.000
EpiLo	19	.078	.136	.000- .500
EpiHi	19	.420	.842	.000- 3.000
Norepinephrine	19	.022	.078	.000- .340
NorepiHr	19	.580	1.390	.000- 4.000
NorepiLo	19	.017	.076	.000- .330
NorepiHi	19	.022	.080	.000- .350
Amrinone	19	2.910	5.130	.000-15.500
AmrinHr	19	1.580	3.120	.000-10.000
AmrinLo	19	1.020	3.060	.000-10.000
AmrinHi	19	2.920	5.150	.000-15.500
NTG	19	1.140	1.580	.000- 4.680
NTGHr	19	5.680	7.630	.000-24.000
NTGLo	19	.410	.850	.000- 3.000
NTGHi	19	1.530	2.360	.000- 8.300
SNP	19	.350	.870	.000- 3.440
SNPHr	19	2.160	5.900	.000-24.000
SNPLo	19	.080	.340	.000- 1.500
SNPHi	19	.510	1.130	.000- 4.000
Isoproterenol*	19	.000	.000	-------
IsoproHr	19	.000	.000	-------
IsoproLo	19	.000	.000	-------
IsoproHi	19	.000	.000	-------
Lidocaine**	19	.970	1.590	.000- 4.000
LidoHr	19	2.320	4.500	.000-16.000
LidoLo	19	.210	.920	.000- 4.000
LidoHi	19	1.000	1.600	.000- 4.000
Procainamide**	19	.000	.000	-------
ProcanHr	19	.000	.000	-------
ProcanLo	19	.000	.000	-------
ProcanHi	19	.000	.000	-------
Neosynephrine	19	.158	.609	.000- 2.650
NeosynHr	19	.740	2.420	.000-10.000
NeosynLo	19	.000	.000	-------
NeosynHi	19	.295	.969	.000- 4.000
Bretylium**	19	.000	.000	-------
BretylHr	19	.000	.000	-------
BretylLo	19	.000	.000	-------
BretylHi	19	.000	.000	-------

Note. # inotropes = Number of inotropes; All drugs in ug/kg/min unless otherwise specified. Dop = Dopamine; Hr = Number of hours infused; Lo = Lower range; Hi = Higher range; Dob = Dobutamine; Epi = Epinephrine; Norepi = Norepinephrine; Amrin = Amrinone; NTG = Nitroglycerine; SNP = Sodium Nitroprusside; Lido = Lidocaine; Procan = Procainamide; Neosyn = Neosynephrine; Bretyl = Bretylium; * = ug/min; ** = mg/min.

Analysis of rhythm strips and 12 lead ECGs during this time revealed that 8 patients (42%) remained in NSR; 1 patient (5%) converted to atrial fibrillation; 8 patients (42%) were in sinus tachycardia; 1 patient (5%) was in sinus tachycardia with PACs, and 2 patients (11%) were in sinus tachycardia with PVCs. One patient (5%) was in a junctional rhythm, and 2 others (11%) continued to show a pattern of atrioventricular heart block. Life-threatening ventricular arrhythmias occurred during this phase with 21% of patients (N = 4) having intermittent runs of ventricular tachycardia, with 3 (16%) progressing to ventricular fibrillation. Temporary pacing continued to be used in 2 patients (11%).

On analysis of the available 12 lead ECGs, 3 patients (16%) showed evidence of anterior ischemia/infarction; 1 patient (5%) had inferior ischemia/infarction; and 1 patient (5%) had left ventricular hypertrophy with left atrial enlargement. ST elevation and T wave changes were apparent in 3 patients (16%), and ST depression in 1 patient (5%).

Cardiac enzymes continued to be elevated during this phase. Marked elevation of LDH, CK, and CKMB signified extensive myocardial damage (Table 4.11).

Table 4.11

Cardiac Enzymes on VAD Implant Day

	N	**μ**	**SD**	**Range**
LDH	5	1417.80	1011.45	500.00-2651.00
CK	10	1422.90	1655.74	135.00-5659.00
CKMB	7	125.43	168.85	15.00- 487.00
FRCKMB	6	.08	.02	.05- .10

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase in U/L; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

Respiratory parameters measured during this time showed that a higher number of patients were now intubated with an increase in the FiO_2 and amount of PEEP used. The resultant PO_2 was also increased (Table 4.12).

Table 4.12

Respiratory Parameters on VAD Implant Day

	N	μ	SD	Range
FiO2	19	.78	.21	.43- 1.00
FiO2SE	19	.11	.09	.00- .31
PO2	19	214.04	109.49	59.50-517.33
PO2SE	19	79.30	56.48	.00-185.56
PEEP	19	4.26	2.99	.00- 10.00
PEEPSE	19	.57	1.15	.00- 3.36
ETT	19	1.00	.58	.00- 2.00

Note. FiO_2 = Fraction of inspired oxygen; SE = Standard error; PO_2 = Partial pressure of oxygen in mmHg; PEEP = Positive end expiratory pressure in cmH_2O; ETT = Number of days intubated.

Renal and hepatic function continued to be evaluated on an ongoing basis (Table 4.13). Serum creatinine (N = 18, μ = 112.94 umol/L, SD = 50.48, range 44 to 204 umol/L) and BUN (N = 16, μ = 7.41 mg/dl, SD = 5.50, range 2.8 to 24.3 mg/dl) were similar to pre-VAD implant values. Mean total bilirubin (μ = 23.00 umol/L, SD = 20.21, range 12 to 59 umol/L) doubled during this time.

Table 4.13

Renal and Hepatic Function on VAD Implant Day

	N	μ	SD	Range
Creatinine	18	112.94	50.48	44.00-204.00
BUN	16	7.41	5.50	2.80- 24.30
U/O	19	232.06	128.03	38.13-516.11
U/OSE	19	133.90	93.36	.00-331.02
TBili	5	23.00	20.21	12.00- 59.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Hematological parameters collected on the VAD insertion day showed evidence of bleeding with resultant transfusion of blood products. Table 4.14 shows hematological variables on the day of VAD institution.

Table 4.14

Hematological Parameters on VAD Implant Day

	N	μ	SD	Range
Hgb	18	101.39	21.63	45.00- 133.00
Hct	18	.30	.07	.13- .39
PTT	18	90.24	47.88	31.00- 150.00
Plt	19	149.21	74.72	48.00- 234.00
CT Loss	19	191.50	397.44	.00-1722.50
CTSE	19	175.07	419.40	.00-1823.48
ACT	13	230.78	73.89	152.00- 442.40
ACTSE	13	40.57	34.39	.00- 99.15
PC	19	8.69	6.52	.00- 22.00
FFP	19	2.26	3.28	.00- 11.00
PltTr	19	6.74	7.78	.00- 24.00
Cryo	19	4.21	9.68	.00- 40.00

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit; PTT = Partial thromboplastin time in seconds; Plt = Platelets in thousands/mm^3; CT Loss = Chest tube loss in mls/hr; CTSE = Chest tube loss standard error; ACT = Activated clotting time in seconds; ACTSE = Activated clotting time standard error; PC = Packed cells transfused in units; FFP = Fresh frozen plasma transfused in units; PltTr = Platelets transfused in units; Cryo = Cryoprecipitate transfused in units.

Coagulation factors (PTINR, PTT) were abnormal with 14 patients (74%) having an elevated PTINR, and a mean PTT of 90.24 seconds (N = 18, SD = 47.88, range 31.0 to 150.0 seconds).

Variables measured on the day of VAD insertion to identify infectious processes showed a slight elevation of WBC (μ = 14.32 10^9/L) with a normal body temperature (μ = 36.88 °C) (Table 4.15). Four patients (21%) had positive cultures including sputum positive for hemophilus influenzae; sputum and bronchial brush specimen positive for streptococcus viridans; sputum positive for Escherichia coli (E. coli) and staphylococcus aureus; and urine positive for enterococcus.

Table 4.15

Infection Status on VAD Implant Day

	N	μ	SD	Range
WBC	17	14.32	6.19	6.10-37.10
TEMP	19	36.88	1.02	34.95-38.77
TEMPSE	19	.64	.47	.00- 1.55

Note. WBC = White blood count measured in 10^9/L; TEMP = Temperature in °C; TEMPSE = Temperature standard error.

Patient Status During Waiting Period for Transplantation

Repeated measures of all variables were collected, when available, during the patients' waiting period for transplant. Seventeen patients were included in this analysis, while 3 others had no transplant waiting days, and were therefore excluded. Of the 7 patients who received cardiac transplantation, the waiting period on the VAD ranged from 9.88 to 104.02 hours (μ = 40.46 hours, SD = 23.72). Neurologic and hemodynamic parameters during the waiting period are shown in Table 4.16.

Table 4.16

Neurologic and Hemodynamic Parameters during Waiting Period

	N	μ	SD	Range
GCS	17	.55	.32	.20- 1.00
HR	17	113.40	20.22	75.10- 151.58
HRSE	17	9.68	6.77	2.39- 24.34
SBP	15	99.33	15.34	61.00- 115.92
SBPSE	15	14.30	6.71	4.47- 24.76
DBP	15	64.14	11.01	47.80- 85.50
DBPSE	15	8.87	4.94	2.77- 17.76
MAP	17	76.46	11.40	50.60- 97.90
MAPSE	17	10.80	5.25	2.70- 19.56
CO	9	5.26	1.38	2.98- 8.23
COSE	9	.72	.46	.00- 1.40
CI	9	2.75	.65	1.66- 3.80
CISE	9	.41	.29	.00- .94
PVRI	9	339.54	136.93	76.14- 504.49
PVRSE	9	92.01	75.75	.00- 250.67
SVRI	9	1933.23	447.09	992.81-2379.83
SVRSE	9	414.66	230.65	.00- 783.86

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 10 or 15 dependent on whether or not the patient is intubated); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg; CO = Cardiac output in L/min; CI = Cardiac index in L/min/m^2; PVRI = Pulmonary vascular resistance index in dynes/sec^5/cm^{-5}/m^2; PVRSE = PVRI standard error; SVRI = Systemic vascular resistance index in dynes/sec^5/cm^{-5}/m^2; SVRSE = SVRI standard error.

Cardiac output ($N = 9$, $\mu = 5.26$ litres/minute, SD = 1.38, range 2.98 to 8.23 litres/minute) was well maintained with VAD flow.

During the transplant waiting period, patients were maintained on an average of 3.10 inotropes ($N = 17$, SD = 1.27, range .00 to 5.25). Forty-one percent ($N = 7$) of patients were on ≤ 5ug/kg/min of Dopamine; 35% of patients ($N = 6$) were on Dopamine at > 5 < 10ug/kg/min; and 24% of patients ($N = 4$) were on Dopamine ≥ 10ug/kg/min. Eighty-eight percent ($N = 15$) of patients were maintained on ≤ 10ug/kg/min of Dobutamine, while 12% ($N = 2$) were on doses of > 10ug/kg/min. Twelve patients (71%) were on ≤ .2ug/kg/min of Epinephrine, and 5 patients were on doses > .2ug/kg/min. Sixteen patients (94%) were on ≤ .2ug/kg/min of Norepinephrine, while 1 patient (6%) was on > .2ug/kg/min. Amrinone was infused at ≤ 10ug/kg/min in 88% of the subjects ($N = 15$), while doses > 10ug/kg/min were used in 2 patients (12%). Sixteen patients (94%) received ≤ 2.5ug/kg/min of NTG and SNP, while 1 (6%) received > 2.5ug/kg/min of both drugs. All patients ($N = 17$, $f = 100\%$) were on ≤ 10ug/min of Isoproterenol. Lidocaine was infused at ≤ 2mg/min and Neosynephrine ≤ .05ug/kg/min in 14 patients (82%), while 3 patients (18%) received doses > 2mg/min and .05ug/kg/min respectively. One patient (6%) received Procainamide at > 2mg/min, the remainder at ≤ 2mg/min, while 2 patients (12%) received Bretylium > 2mg/min, and the other patients ($N = 15$, $f = 88\%$) at ≤ 2mg/min.

Table 4.17

Inotropic Support During Waiting Period

	N	μ	SD	Range
# Inotropes	17	3.100	1.270	.000- 5.250
Dopamine	17	6.780	6.680	.001-21.870
DopHr	17	13.290	10.080	.000-24.000
DopLo	17	5.500	5.950	.000-20.000
DopHi	17	7.660	7.240	.000-23.300
Dobutamine	17	2.470	5.500	.000-18.540
DobHr	17	3.750	8.080	.000-24.000
DobLo	17	1.670	4.640	.000-17.050
DobHi	17	2.830	6.520	.000-20.000
Epinephrine	17	.149	.190	.000- .760
EpiHr	17	12.820	9.810	.000-24.000
EpiLo	17	.104	.132	.000- .500
EpiHi	17	.202	.246	.000- .900
Norepinephrine	17	.025	.075	.000- .287
NorepiHr	17	2.000	5.600	.000-20.000
NorepiLo	17	.020	.065	.000- .260
NorepiHi	17	.032	.092	.000- .333
Amrinone	17	2.300	4.500	.000-13.870
AmrinHr	17	3.850	7.310	.000-20.000
AmrinLo	17	1.960	4.410	.000-13.100
AmrinHi	17	2.840	4.860	.000-15.500
NTG	17	.840	1.380	.000- 5.320
NTGHr	17	7.660	9.690	.000-24.000
NTGLo	17	.580	1.280	.000- 5.280
NTGHi	17	.980	1.480	.000- 5.400
SNP	17	.180	.750	.000- 3.100
SNPHr	17	1.410	5.820	.000-24.000
SNPLo	17	.170	.690	.000- 2.840
SNPUp	17	.210	.870	.000- 3.580
Isoproterenol*	17	.001	.002	.000- .010
IsoproHr	17	.180	.730	.000- 3.000
IsoproLo	17	.000	.000	-------
IsoproHi	17	.001	.006	.000- .030
Lidocaine**	17	1.000	1.460	.000- 4.000
LidoHr	17	4.660	7.370	.000-23.000
LidoLo	17	.750	1.400	.000- 4.000
LidoHi	17	1.100	1.570	.000- 4.000
Procainamide**	17	.210	.860	.000- 3.540
ProcanHr	17	.740	3.030	.000-12.500
ProcanLo	17	.120	.490	.000- 2.000
ProcanHi	17	.240	.970	.000- 4.000
Neosynephrine	17	.140	.483	.000- 2.000
NeosynHr	17	.820	1.870	.000- 5.500
NeosynLo	17	.118	.485	.000- 2.000
NeosynHi	17	.145	.484	.000- 2.000
Bretylium**	17	.300	.850	.000- 2.900
BretylHr	17	1.880	5.360	.000-18.000
BretylLo	17	.260	.730	.000- 2.500
BretylHi	17	.320	.900	.000- 3.000

Note. # inotropes = Number of inotropes; All drugs in ug/kg/min unless otherwise specified. Dop = Dopamine; Hr = Number of hours infused; Lo = Lower range; Hi = Higher range; Dob = Dobutamine; Epi = Epinephrine; Norepi = Norepinephrine; Amrin = Amrinone; NTG = Nitroglycerine; SNP = Sodium Nitroprusside; Lido = Lidocaine; Procan = Procainamide; Neosyn = Neosynephrine; Bretyl = Bretylium; * = ug/min; ** = mg/min.

Rhythm strip and 12 lead ECG analysis during the waiting period revealed that 12 patients (71%) were in NSR; 1 patient (6%) was in atrial fibrillation; 11 patients (65%) were in sinus tachycardia; 4 patients (24%) were in sinus tachycardia with intermittent PVCs; 1 patient (6%) was in an accelerated junctional rhythm; 1 patient (6%) had a run of SVT; 1 patient (6%) had continued episodes of ventricular tachycardia; 1 patient (6%) had an idioventricular rhythm; and 2 patients (12%) developed an agonal rhythm and ultimately died. Three patients (18%) required temporary pacing during the wait for cardiac transplantation.

Twelve lead ECG analysis during this phase was difficult due to the small number of ECGs performed (N = 3), however 1 patient (6%) continued to show evidence for anterior ischemia or infarction, and 2 others (12%) showed inferior ischemia/infarction. ST depression and T wave changes were present in 1 patient (6%), while ST elevation was evident in the others (N = 2, f = 12%).

Cardiac enzymes remained elevated during the waiting period and signified ongoing myocardial ischemia or damage occurring with the VAD in situ. Table 4.18 shows the cardiac enzyme values for this period of time.

Table 4.18

Cardiac Enzymes During Waiting Period

	N	μ	SD	Range
LDH	5	1984.95	1516.76	387.00-4000.00
CK	10	2894.78	2378.46	140.00-7500.00
CKMB	9	115.25	147.15	5.00- 462.00
FRCKMB	8	.05	.05	.01- .16

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase in U/L; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

Patients required slightly less FiO_2 (μ = .72) during the waiting period, however PEEP requirements increased (μ = 6.01 cmH_2O) and arterial PO_2 decreased (μ = 189.02 mmHg). Table 4.19 displays the respiratory parameters for patients awaiting transplantation. Average number of days intubated while awaiting transplantation was 2.49 (N = 17, SD = .82, range 1 to 4 days).

Table 4.19

Respiratory Parameters During Waiting Period

	N	**μ**	**SD**	**Range**
FiO2	17	.72	.20	.32- 1.00
FiO22SE	17	.09	.06	.00- .21
PO2	17	189.02	136.09	74.89-442.00
PO2SE	17	49.04	48.20	8.43-180.26
PEEP	17	6.01	1.91	2.92- 10.00
PEEPSE	17	.53	.87	.00- 2.59
ETT	17	2.49	.82	1.00- 4.00

Note. FiO$_2$ = Fraction of inspired oxygen; SE = Standard error; PO$_2$ = Partial pressure of oxygen in mmHg; PEEP = Positive end expiratory pressure in cmH$_2$0; ETT = Number of days intubated.

Renal function deteriorated during the transplant waiting period and ultimately resulted in the removal of 4 patients (20%) from the transplant list with subsequent death in 3 of those patients (15%). Hepatic function also deteriorated with a mean total bilirubin of 44.71 umol/L (N = 7, SD = 34.09, range 13 to 116 umol/L).

Table 4.20

Renal and Hepatic Function During Waiting Period

	N	**μ**	**SD**	**Range**
Creatinine	17	185.52	115.96	48.00-433.00
BUN	16	10.85	8.58	4.60- 38.50
U/O	17	124.16	85.73	5.80-331.06
U/OSE	17	71.36	39.31	4.66-146.02
TBili	7	44.71	34.09	13.00-116.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Hematological variables measured during the waiting period for transplant showed an improvement in clotting function with decreased blood loss and lower transfusion requirements (Table 4.21). Ten patients (59%) continued to have an elevated PTINR, while mean PTT (N = 17) was 85.12 seconds.

Table 4.21

Hematological Parameters During Waiting Period

	N	μ	SD	Range
Hgb	17	104.96	17.53	70.00-137.00
Hct	17	.31	.05	.20- .40
PTT	17	85.12	38.70	38.30-150.00
Plt	16	101.16	49.51	43.00-233.00
CTLoss	17	146.24	251.56	.00-827.09
CTSE	17	107.12	170.38	.00-530.02
ACT	10	219.04	78.43	127.50-413.48
ACTSE	10	41.89	25.57	17.63- 25.57
PC	17	7.99	8.68	1.00- 31.00
FFP	17	2.05	4.04	.00- 14.00
PltTr	17	4.24	6.94	.00- 22.00
Cryo	17	5.30	11.24	.00- 44.00

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit; PTT = Partial thromboplastin time in seconds; Plt = Platelets in thousands/mm^3; CT Loss = Chest tube loss in mls/hr; CTSE = Chest tube loss standard error; ACT = Activated clotting time in seconds; ACTSE = Activated clotting time standard error; PC = Packed cells transfused in units; FFP = Fresh frozen plasma transfused in units; PltTr = Platelets transfused in units; Cryo = Cryoprecipitate transfused in units.

Number of infectious episodes increased during the transplant waiting period. Numerous positive cultures were identified in 8 patients (47%), which included blood positive for staphylococcus aureus, clostridium perfringens, E. coli, and coagulase negative staphylococcus. Sputum cultured positive for proteus miribalis, clostridium perfringens, staphylococcus aureus, beta hemolytic streptococcus, hemophilus influenzae, hafnia alvei, neisseria, and proteus. Other less common media for infection included a nasopharyngeal swab positive for staphylococcus aureus, a urine culture positive for yeast, and a VAD line culture positive for coagulase negative staphylococcus and yeast. Four patients (24%) developed postoperative sepsis, resulting in 2 patients (12%) being removed from the transplant list. One patient (6%) ultimately deceased from septic complications.

Table 4.22

Infection Status During Waiting Period

	N	μ	SD	Range
WBC	16	11.79	3.97	4.10-19.00
TEMP	17	37.50	.91	35.70-39.18
TEMPSE	17	.58	.30	.19- 1.45

Note. WBC = White blood count measured in 10^9/L; TEMP = Temperature in °C; TEMPSE = Temperature standard error.

Patient Status on Transplant Day

Of the 20 patients, 7 (35%) survived to cardiac transplantation; 12 deceased during the transplant waiting period of complications of VAD support; and 1 survived without transplantation and was subsequently weaned from VAD support. Variables for the 7 patients who received a cardiac transplant are described here. As shown in Table 4.24, neurological and cardiac function were depressed on the transplant day.

Patients were on maximal doses of inotropic therapy and reported the largest number of inotropes ($N = 7$, $\mu = 4.86$ inotropes, $SD = 1.35$, range 3 to 7 inotropes) on the cardiac transplant day. Only 1 patient (14%) was on Dopamine at ≤ 5ug/kg/min; 3 patients (43%) were on Dopamine > 5 < 10ug/kg/min; and 3 patients (43%) were on > 10ug/kg/min of the drug. Eighty-six percent of patients ($N = 6$) were on Dobutamine at ≤ 10ug/kg/min, while one other patient was on > 10ug/kg/min. All transplanted patients ($N = 7$) were on ≤ .2ug/kg/min of Epinephrine, ≤ 10ug/kg/min of Amrinone, and ≤ 2mg/min of Procainamide and Bretylium. Six patients (86%) were on Norepinephrine at ≤ .2ug/kg/min, NTG and SNP at ≤ 2.5 ug/kg/min, Isoproterenol at ≤ 10ug/min, Lidocaine at ≤ 2mg/min, and Neosynephrine at ≤ .05ug/kg/min. One patient (14%) was on Norepinephrine at > .2ug/kg/min, NTG and SNP at > 2.5ug/kg/min, Isoproterenol at > 10ug/min, Lidocaine at > 2mg/min, and Neosynephrine at > .05ug/kg/min, respectively.

Table 4.23

Neurologic and Hemodynamic Status on Transplant Day

	N	**μ**	**SD**	**Range**
GCS	7	.73	.38	.20- 1.00
HR	7	116.18	8.23	107.35- 131.72
HRSE	7	14.77	9.32	7.87- 34.88
SBP	7	109.08	21.96	67.13- 129.00
SBPSE	7	19.14	6.03	11.11- 28.46
DBP	7	61.37	7.77	50.13- 73.35
DBPSE	7	10.05	2.64	6.90- 13.83
MAP	7	77.89	11.33	54.56- 88.31
MAPSE	7	11.31	3.01	7.34- 16.10
CO	3	2.91	.76	2.03- 3.41
COSE	3	.59	.56	.00- 1.11
CI	3	1.65	.63	.95- 2.18
CISE	3	.36	.37	.00- .73
PVRI	3	244.06	140.36	84.21- 347.19
PVRSE	3	67.61	60.29	.00- 115.77
SVRI	3	3079.56	190.32	2913.00-3287.00
SVRSE	3	621.93	644.19	.00-1286.29

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 10 or 15 dependent on whether or not the patient is intubated); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg; CO = Cardiac output in L/min; CI = Cardiac index in L/min/m^2; PVRI = Pulmonary vascular resistance index in dynes/sec^2/cm^{-5}/m^2; PVRSE = PVRI standard error; SVRI = Systemic vascular resistance index in dynes/sec^2/cm^{-5}/m^2; SVRSE = SVRI standard error.

Analysis of the rhythm strips and 12 lead ECGs done on the transplant day show that 3 patients (43%) were in NSR or sinus tachycardia, 1 patient (14%) was in atrial fibrillation, 1 patient (14%) alternated between a junctional and accelerated junctional rhythm, and 1 patient (14%) had intermittent episodes of SVT. No ventricular arrhythmias were noted, however 1 patient (14%) developed an agonal rhythm and died on the transplant day. Only 1 patient (14%) required temporary pacing due to the inability to maintain an intrinsic heartrate and blood pressure.

One patient (14%) continued to show evidence of anterior ischemia on 12 lead ECG, and 1 patient (14%) showed signs of left ventricular hypertrophy. No ST depression or elevation were noted, however there continued to be T changes evident on one postoperative ECG.

Table 4.24

Inotropic Support on Transplant Day

	N	μ	SD	Range
# Inotropes	7	4.860	1.350	4.000- 7.000
Dopamine	7	10.920	8.230	.000-23.800
DopHr	7	12.290	7.160	.000-19.000
DopLo	7	4.990	6.930	.000-19.300
DopHi	7	12.170	8.080	.000-25.000
Dobutamine	7	7.020	8.700	.000-23.900
DobHr	7	5.860	6.990	.000-19.000
DobLo	7	3.600	7.490	.000-20.000
DobHi	7	7.170	9.060	.000-25.000
Epinephrine	7	.088	.087	.000- .200
EpiHr	7	10.860	10.460	.000-24.000
EpiLo	7	.046	.074	.000- .200
EpiHi	7	.114	.111	.000- .250
Norepinephrine	7	.054	.122	.000- .330
NorepiHr	7	3.430	5.970	.000-16.000
NorepiLo	7	.034	.074	.000- .200
NorepiHi	7	.061	.141	.000- .380
Amrinone	7	2.500	4.330	.000-10.000
AmrinHr	7	3.140	6.090	.000-16.000
AmrinLo	7	1.430	3.780	.000-10.000
AmrinHi	7	2.500	4.330	.000-10.000
NTG	7	1.590	1.800	.000- 5.180
NTGHr	7	8.000	8.490	.000-17.000
NTGLo	7	1.090	1.840	.000- 5.000
NTGHi	7	1.900	2.030	.000- 5.500
SNP	7	1.190	1.630	.000 -4.120
SNPHr	7	4.140	6.740	.000-17.000
SNPLo	7	.610	1.240	.000- 3.300
SNPUp	7	1.670	2.160	.000- 5.000
Isoproterenol*	7	.550	.980	.000- 2.570
IsoproHr	7	5.570	5.500	.000-11.000
IsoproLo	7	.300	.750	.000- 2.000
IsoproHi	7	.680	1.120	.000- 2.900
Lidocaine**	7	.570	1.510	.000- 4.000
LidoHr	7	.860	2.270	.000- 6.000
LidoLo	7	.000	.000	-------
LidoHi	7	.570	1.510	.000- 4.000
Procainamide**	7	.290	.760	.000- 2.000
ProcanHr	7	.570	1.510	.000- 4.000
ProcanLo	7	.000	.000	-------
ProcanHi	7	.290	.760	.000- 2.000
Neosynephrine	7	.144	.382	.000- 1.010
NeosynHr	7	1.140	3.020	.000- 8.000
NeosynLo	7	.089	.234	.000- .620
NeosynHi	7	.229	.605	.000- 1.600
Bretylium**	7	.000	.000	-------
BretylHr	7	.000	.000	-------
BretylLo	7	.000	.000	-------
BretylHi	7	.000	.000	-------

Note. # inotropes = Number of inotropes; All drugs in ug/kg/min unless otherwise specified. Dop = Dopamine; Hr = Number of hours infused; Lo = Lower range; Hi = Higher range; Dob = Dobutamine; Epi = Epinephrine; Norepi = Norepinephrine; Amrin = Amrinone; NTG = Nitroglycerine; SNP = Sodium Nitroprusside; Lido = Lidocaine; Procan = Procainamide; Neosyn = Neosynephrine; Bretyl = Bretylium; * = ug/min; ** = mg/min.

Cardiac enzymes remained elevated on the transplant day with a decrease in LDH and CK, but an increase in values for CKMB and FRCKMB.

Table 4.25 displays these values.

Table 4.25

Cardiac Enzymes on Transplant Day

	N	μ	SD	Range
LDH	3	1250.33	610.34	652.00-1872.00
CK	5	2470.00	1218.57	532.00-3763.00
CKMB	4	142.50	87.03	65.00- 260.00
FRCKMB	4	.08	.04	.03- .12

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase in U/L; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

Respiratory function of patients measured on the transplant day is shown in Table 4.26. FiO_2 requirements were slightly less than during the waiting period (M = .68, SD = .21, range .42 to 1.00). Arterial PO_2 and PEEP were also lower than during the transplant waiting period. Average number of days intubated on the transplant day was 2.29 (SD =1.25, range 0 to 4 days).

Table 4.26

Respiratory Parameters on Transplant Day

	N	μ	SD	Range
FiO2	7	.68	.21	.42- 1.00
FiO2SE	7	.14	.09	.00- .25
PO2	7	166.97	96.68	88.00-370.50
PO2SE	7	50.54	30.23	25.98-112.01
PEEP	7	5.32	2.52	.00- 7.56
PEEPSE	7	1.49	1.81	.00- 4.93
ETT	7	2.29	1.25	.00- 4.00

Note. FiO_2 = Fraction of inspired oxygen; SE = Standard error; PO_2 = Partial pressure of oxygen in mmHg; PEEP = Positive end expiratory pressure in cmH_2O; ETT = Number of days intubated.

Renal function remained stable on the day of transplant with a slight improvement in creatinine, BUN, and urine output. Total bilirubin improved significantly on the transplant day (Table 4.27).

Table 4.27

Renal and Hepatic Function on Transplant Day

	N	μ	SD	Range
Creatinine	7	143.14	82.33	48.00-303.00
BUN	7	9.16	6.17	4.00- 21.40
U/O	7	133.03	89.43	9.17-284.38
U/OSE	7	89.40	66.38	6.46-187.97
TBili	3	10.00	2.65	7.00- 12.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Bleeding status of the patients on the transplant day is shown in Table 4.28. Hemoglobin and hematocrit were decreased while coagulation factors were increased. Eighty-six percent of patients had a high PTINR (N = 6), while 14% (N = 1) had a normal level. Transfusion requirements were high with patients receiving an average of 17.29 units of packed cells (N = 7, SD = 4.72, range 11 to 25 units); 2.71 units of plasma (N = 7, SD = 1.80, range 1 to 6 units); 14.00 units of platelets (N = 7, SD = 4.32, range 6 to 20 units); and 9.14 units of cryoprecipitate (N = 7, SD = 6.09, range 0 to 18 units).

Infection parameters (Table 4.29) on the transplant day included a mean WBC of 11.76 10^9/L, and mean temperature of 36.88 °C (N = 7, SD = .48, range 36.28 to 37.49OC). Cultures taken from 2 patients on the transplant day were growing pathogens. One patient was identified as having blood positive for candida albicans, and sputum and urine positive for staphylococcus aureus; and the second patient was positive for candida albicans, hafnia alvei, and neisseria in sputum, and yeast in the urine.

Table 4.28

Hematological Parameters on Transplant Day

	N	μ	SD	Range
Hgb	7	93.57	15.56	67.00-113.00
Hct	7	.27	.05	.20- .32
PTT	7	101.31	49.60	42.00-150.00
Plt	7	94.57	44.49	44.00-172.00
CT Loss	6	203.62	280.24	34.00-761.79
CTSE	6	230.01	377.80	36.44-998.78
ACT	7	198.59	64.67	129.50-336.79
ACTSE	7	30.15	41.55	.00-119.08
PC	7	17.29	4.72	11.00- 25.00
FFP	7	2.71	1.80	1.00- 6.00
PltTr	7	14.00	4.32	6.00- 20.00
Cryo	7	9.14	6.09	.00- 18.00

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit; PTT = Partial thromboplastin time in seconds; Plt = Platelets in thousands/mm^3; CT Loss = Chest tube loss in mls/hr; CTSE = Chest tube loss standard error; ACT = Activated clotting time in seconds; ACTSE = Activated clotting time standard error; PC = Packed cells transfused in units; FFP = Fresh frozen plasma transfused in units; PltTr = Platelets transfused in units; Cryo = Cryoprecipitate transfused in units.

Table 4.29

Infection Parameters on Transplant Day

	N	μ	SD	Range
WBC	7	11.76	4.54	6.10-16.90
TEMP	7	36.88	.48	36.28-37.49
TEMPSE	7	.80	.48	.13- 1.55

Note. WBC = White blood count measured in 10^9/L; TEMP = temperature in °C; TEMPSE = Temperature standard error.

Patient Status in the Early Postoperative Period

Data collected from postoperative intensive care unit (ICU) day 1 to day 8 were included in this analysis. Seven patients were included on postoperative day 1, 6 patients were included on postoperative days 2 to 5, 5 patients were included on postoperative day 6, and 4 patients were remaining on postoperative day 7 and 8. Early transfer of stable patients out of the ICU setting (N = 1), and death in the early postoperative period (N = 2) accounted for attrition in this sample.

Neurologic and hemodynamic status of patients in the early postoperative period are shown in Table 4.30.

Table 4.30

Neurologic and Hemodynamic Status in Early Postoperative Period

	N	μ	SD	Range
GCS	7	.78	.28	.20- 1.00
HR	7	114.94	10.47	98.12- 131.21
HRSE	7	8.10	4.00	4.83- 15.73
SBP	7	124.88	14.63	107.15- 144.32
SBPSE	7	14.86	3.04	7.64- 17.33
DBP	7	67.48	9.40	53.03- 79.09
DBPSE	7	7.85	1.52	6.43- 10.19
MAP	7	84.19	9.16	67.67- 92.02
MAPSE	7	9.20	1.35	7.68- 10.99
CO	7	4.92	.99	3.05- 6.39
COSE	7	.62	.19	.30- .84
CI	7	2.62	.35	2.03- 3.19
CISE	7	.33	.08	.19- .42
PVRI	7	283.75	108.16	123.23- 473.00
PVRSE	7	69.41	34.42	22.44- 117.00
SVRI	7	2142.64	529.14	1526.23-3096.24
SVRSE	7	330.16	152.57	130.93- 577.56

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 10 or 15 dependent on whether or not the patient is intubated); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg; CO = Cardiac output in L/min; CI = Cardiac index in L/min/m^2; PVRI = Pulmonary vascular resistance index in dynes/sec^2/cm^{-5}/m^2; PVRSE = PVRI standard error; SVRI = Systemic vascular resistance index in dynes/sec^2/cm^{-5}/m^2; SVRSE = SVRI standard error.

In the early postoperative period, patients were on an average of 3.54 inotropes (N = 7, SD = 1.28, range 1.50 to 5.33). Seventy-one percent (N = 5) of patients were on Dopamine ≤ 5ug/kg/min; 14% (N = 1) of patients were on Dopamine > 5 < 10ug/kg/min; and 14% (N = 1) of patients were on Dopamine ≥ 10ug/kg/min. All 7 patients were on Dobutamine at ≤ 10ug/kg/min; Epinephrine at ≤ .2ug/kg/min; Norepinephrine at ≤ .2ug/kg/min; Lidocaine, Procainamide, and Bretylium at ≤ 2mg/min; and Neosynephrine at ≤ .05ug/kg/min. Eighty-six percent of patients (N = 6) were on Amrinone at ≤ 10ug/kg/min, NTG and SNP at ≤ 2.5ug/kg/min, and Isoproterenol at ≤ 10ug/min, while 14% (N = 1) of patients were on Amrinone at > 10ug/kg/min, NTG and SNP at > 2.5ug/kg/min, and Isoproterenol at > 10ug/min, respectively.

Table 4.31

Inotropic Support in Early Postoperative Period

	N	**μ**	**SD**	**Range**
#Inotropes	7	3.540	1.280	1.500- 5.330
Dopamine	7	5.510	4.330	.630-14.010
DopHr	7	18.840	8.940	.330-24.000
DopLo	7	4.700	4.010	.000-12.470
DopHi	7	6.020	4.650	.830-14.970
Dobutamine	7	2.160	3.560	.000- 9.840
DobHr	7	4.480	7.970	.000-22.000
DobLo	7	1.240	2.910	.000- 8.290
DobHi	7	2.520	3.920	.000-10.140
Epinephrine	7	.057	.059	.000- .158
EpiHr	7	10.430	9.640	.000-24.000
EpiLo	7	.037	.049	.000- .126
EpiHi	7	.070	.070	.000- .179
Norepinephrine	7	.017	.034	.000- .095
NorepiHr	7	2.220	3.090	.000- 6.830
NorepiLo	7	.005	.012	.000- .033
NorepiHi	7	.024	.044	.000- .117
Amrinone	7	3.400	4.410	.000-11.370
AmrinHr	7	6.640	9.130	.000-22.170
AmrinLo	7	2.330	3.350	.000 -8.250
AmrinHi	7	4.020	6.770	.000-60.000
NTG	7	1.200	1.880	.000- 5.560
NTGHr	7	11.330	11.330	.000-24.000
NTGLo	7	1.030	1.820	.000- 5.210
NTGHi	7	1.460	2.360	.000- 7.050
SNP	7	.960	1.810	.000- 5.220
SNPHr	7	7.300	10.470	.000-24.000
SNPLo	7	.520	1.070	.000- 3.110
SNPHi	7	1.460	2.570	.000- 7.480
Isoproterenol*	7	.250	.460	.000- 1.300
IsoproHr	7	9.180	7.480	.000-21.500
IsoproLo	7	.180	.330	.000- .940
IsoproHi	7	.310	.550	.000- 1.460
Lidocaine**	7	.130	.360	.000- 1.030
LidoHr	7	.720	2.030	.000- 5.750
LidoLo	7	.060	.180	.000- .500
LidoHi	7	.190	.530	.000- 1.500
Procainamide**	7	.000	.000	-------
ProcanHr	7	.000	.000	-------
ProcanLo	7	.000	.000	-------
ProcanHi	7	.000	.000	-------
Neosynephrine	7	.012	.035	.000- .098
NeosynHr	7	.290	.830	.000- 2.330
NeosynLo	7	.000	.000	-------
NeosynHi	7	.016	.046	.000- .130
Bretylium**	7	.160	.440	.000- 1.250
BretylHr	7	2.000	5.660	.000-16.000
BretylLo	7	.130	.370	.000- 1.030
BretylHi	7	.170	.490	.000- 1.380

Note. # inotropes = Number of inotropes; All drugs in ug/kg/min unless otherwise specified. Dop = Dopamine; Hr = Number of hours infused; Lo = Lower range; Hi = Higher range; Dob = Dobutamine; Epi = Epinephrine; Norepi = Norepinephrine; Amrin = Amrinone; NTG = Nitroglycerine; SNP = Sodium Nitroprusside; Lido = Lidocaine; Procan = Procainamide; Neosyn = Neosynephrine; Bretyl = Bretylium; * = ug/min; ** = mg/min.

Rhythm strip analysis during the early postoperative period found that 2 patients (29%) alternated between NSR and sinus tachycardia. One patient (14%) also had PACs. One patient (14%) experienced episodes of atrial fibrillation, 1 patient (14%) had a junctional tachycardia, and 2 patients (29%) required temporary pacing at some point during the early postoperative phase.

Twelve lead ECG analysis revealed evidence of anterior ischemia/ infarct in 1 patient (14%), inferior ischemia/ infarct in 2 patients (29%), left atrial enlargement in 1 patient (14%), and T changes in 2 patients (29%). Cardiac enzymes decreased during the postoperative period (Table 4.32).

Table 4.32

Cardiac Enzymes in the Early Postoperative Period

	N	μ	SD	Range
LDH	3	1207.46	904.80	539.00-2237.00
CK	6	2842.06	1982.72	266.00-5264.00
CKMB	5	54.27	53.09	16.00- 145.00
FRCKMB	5	.03	.04	.01- .10

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase in U/L; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

Respiratory function (Table 4.33) improved during the early postoperative period with mean FiO_2 of .47 (N = 7, SD = .13, range .30 to .69). Mean arterial PO_2 decreased in conjunction with lower levels of FiO_2 (N = 7, μ = 96.22 mmHg, SD = 15.55, range 82.04 to 131.62 mmHg). PEEP requirements averaged 6.77 cmH_2O (N = 7, SD = 2.77, range 1.20 to 10.08 cmH_2O). Average number of days intubated was 6.05 (N = 7, SD = 1.92, range 2.25 to 8.50 days).

Table 4.33

Respiratory Parameters During the Early Postoperative Period

	N	μ	SD	Range
FiO2	7	.47	.13	.30- .69
FiO2SE	7	.04	.03	.00- .10
PO2	7	96.22	15.55	82.04-131.62
PO2SE	7	17.45	8.22	7.65- 28.05
PEEP	7	6.77	2.77	1.20- 10.08
PEEPSE	7	.98	.98	.00- 2.86
ETT	7	6.05	1.92	2.25- 8.50

Note. FiO_2 = Fraction of inspired oxygen; SE = Standard error; PO_2 = Partial pressure of oxygen in mmHg; PEEP = Positive end expiratory pressure in cmH_2O; ETT = Number of days intubated.

Renal and hepatic function deteriorated during the early postoperative period. Table 4.34 shows average serum creatinine, BUN, urine output, and total bilirubin levels during this time.

Table 4.34

Renal and Hepatic Function During the Early Postoperative Period

	N	μ	SD	Range
Creatinine	7	224.64	113.18	64.00-381.00
BUN	7	15.76	8.21	5.90- 30.30
U/O	7	126.66	79.04	23.28-238.59
U/OSE	7	67.19	44.86	13.23-128.08
TBili	7	54.40	45.07	19.00-142.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Measures of hematological function improved throughout the early postoperative period. Bleeding and transfusion requirements decreased, while coagulation factors stabilized. Five patients (71%) had a PTINR within normal limits. Two others (29%) continued to have a PTINR that was slightly elevated. Table 4.35 shows hematological parameters during the early postoperative period.

Table 4.35

Hematological Parameters During the Early Postoperative Period

	N	μ	SD	Range
Hgb	7	112.20	12.68	100.00-138.00
Hct	7	.33	.04	.30- .40
PTT	7	43.48	20.17	27.00- 89.70
Plt	7	75.46	25.00	45.00-122.00
CT Loss	7	17.55	10.27	.56- 32.60
CTSE	7	19.03	15.46	.83- 50.58
ACT	3	181.01	14.87	166.25-196.00
ACTSE	3	14.66	1.91	12.72- 16.55
PC	7	1.37	.90	1.00- 3.00
FFP	7	.41	.78	.00- 2.00
PltTr	7	2.91	3.07	.00- 8.00
Cryo	7	1.13	2.10	.00- 5.00

Note. Hgb = hemoglobin in gm/L; Hct = hematocrit; PTT = partial thromboplastin time in seconds; Plt = platelets in thousands/mm^3; CT Loss = chest tube loss in mls/hr; CTSE = chest tube loss standard error; ACT = activated clotting time in seconds; ACTSE = activated clotting time standard error; PC = packed cells transfused in units; FFP = fresh frozen plasma transfused in units; PltTr = platelets transfused in units; Cryo = cryoprecipitate transfused in units.

Variables measured during the early postoperative period to identify ongoing infectious processes showed that all 7 patients who had cultures taken were positive for infection. Coagulase negative staphylococcus, candida albicans, and streptococcus viridans were commonly isolated pathogens. Mean WBC (M = 17.89 10^9/L, SD = 5.76, range 11.2 to 27.6 10^9/L) was elevated (Table 4.36), however temperature remained within normal limits.

Table 4.36

Infection Status During Early Postoperative Period

	N	μ	SD	Range
WBC	7	17.89	5.76	11.20-27.60
TEMP	7	36.97	.64	36.03-38.16
TEMPSE	7	.49	.11	.31- .68

Note. WBC = White blood count measured in 10^9/L; TEMP = Temperature in °C; TEMPSE = Temperature standard error.

Patient Status in the Late Postoperative Period

Data included in this analysis were collected from postoperative ICU day 9 to postoperative ICU day 34. Three patients remained in the ICU from day 9 to day 24 requiring prolonged ventilatory support, and 2 patients remained from day 25 to day 34 for prolonged hemodynamic monitoring and support according to the accepted practice guidelines in the early days of the transplant program. Neurologic and hemodynamic variables are shown in Table 4.37.

Table 4.37

Neurologic and Hemodynamic Parameters in Late Postoperative Period

	N	μ	SD	Range
GCS	3	1.00	.01	.99- 1.00
HR	3	101.87	2.71	99.62- 104.88
HRSE	3	4.64	1.22	3.72- 6.03
SBP	3	140.49	10.29	132.32- 152.05
SBPSE	3	13.78	2.68	11.67- 16.79
DBP	3	80.01	6.08	75.78- 86.98
DBPSE	3	8.21	1.35	7.18- 9.73
MAP	3	97.37	4.83	94.05- 102.91
MAPSE	3	9.13	2.36	6.81- 11.52
CO	2	4.41	.94	3.75- 5.07
COSE	2	.40	.30	.19- .61
CI	2	2.64	.19	2.50- 2.77
CISE	2	.24	.16	.12- .35
PVRI	2	255.51	104.66	181.50- 329.52
PVRSE	2	68.00	42.81	37.73- 98.26
SVRI	2	2619.66	413.43	2327.33-2912.00
SVRSE	2	233.93	153.28	125.54- 342.31

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 10 or 15 dependent on whether or not the patient is intubated); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg; CO = Cardiac output in L/min; CI = Cardiac index in L/min/m^2; PVRI = Pulmonary vascular resistance index in dynes/sec^2/cm^{-5}/m^2; PVRSE = PVRI standard error; SVRI = Systemic vascular resistance index in dynes/sec^2/cm^{-5}/m^2; SVRSE = SVRI standard error.

In the late postoperative period, patients were on minimal amounts of inotropic support. Average number of inotropes was 1.93 (N = 3, SD = 1.04, range 1.06 to 3.08). All patients (N = 3) were on Dopamine at ≤ 5ug/kg/min; Dobutamine at ≤ 10ug/kg/min; NTG and SNP at ≤ 2.5ug/kg/min; Isoproterenol at ≤ 10ug/min; and Lidocaine and Procainamide at ≤ 2mg/min. No patients were on Epinephrine, Norepinephrine, Amrinone, Neosynephrine, or Bretylium infusions during the late postoperative period.

Table 4.38

Inotropic Support in the Late Postoperative Period

	N	**μ**	**SD**	**Range**
# Inotropes	3	1.930	1.040	1.060- 3.080
Dopamine	3	2.330	1.140	1.230- 3.500
DopHr	3	15.500	6.780	8.000-21.190
DopLo	3	2.040	1.090	1.120- 3.250
DopHi	3	2.390	1.160	1.300- 3.610
Dobutamine	3	2.650	4.590	.000- 7.950
DobHr	3	5.180	8.970	.000-15.540
DobLo	3	2.160	3.730	.000- 6.470
DobHi	3	3.090	5.350	.000- 9.270
Epinephrine	3	.000	.000	-------
EpiHr	3	.000	.000	-------
EpiLo	3	.000	.000	-------
EpiHi	3	.000	.000	-------
Norepinephrine	3	.000	.000	-------
NorepiHr	3	.000	.000	-------
NorepiLo	3	.000	.000	-------
NorepiHi	3	.000	.000	-------
Amrinone	3	.000	.000	-------
AmrinHr	3	.000	.000	-------
AmrinLo	3	.000	.000	-------
AmrinHi	3	.000	.000	-------
NTG	3	.880	1.070	.000- 2.070
NTGHr	3	8.420	7.300	.000-12.920
NTGLo	3	.760	.900	.000- 1.750
NTGHi	3	.840	.980	.000- 1.920
SNP	3	1.010	.300	.660- 1.210
SNPHr	3	10.400	5.420	5.190-16.000
SNPLo	3	.610	.270	.340- .890
SNPHi	3	1.360	.320	1.000- 1.620
Isoproterenol*	3	.040	.070	.000- .120
IsoproHr	3	1.780	3.090	.000- 5.350
IsoproLo	3	.030	.050	.000- .090
IsoproHi	3	.040	.070	.000- .130
Lidocaine**	3	.160	.280	.000- .490
LidoHr	3	1.030	1.780	.000- 3.080
LidoLo	3	.000	.000	-------
LidoHi	3	.190	.330	.000- .580
Procainamide**	3	.060	.110	.000- .190
ProcanHr	3	.530	.910	.000- 1.580
ProcanLo	3	.010	.020	.000- .040
ProcanHi	3	.080	.130	.000- .230
Neosynephrine	3	.000	.000	-------
NeosynHr	3	.000	.000	-------
NeosynLo	3	.000	.000	-------
NeosynHi	3	.000	.000	-------
Bretylium**	3	.000	.000	-------
BretylHr	3	.000	.000	-------
BretylLo	3	.000	.000	-------
BretylHi	3	.000	.000	-------

Note. # inotropes = Number of inotropes; All drugs in ug/kg/min unless otherwise specified. Dop = Dopamine; Hr = Number of hours infused; Lo = Lower range; Hi = Higher range; Dob = Dobutamine; Epi = Epinephrine; Norepi = Norepinephrine; Amrin = Amrinone; NTG = Nitroglycerine; SNP = Sodium Nitroprusside; Lido = Lidocaine; Procan = Procainamide; Neosyn = Neosynephrine; Bretyl = Bretylium; * = ug/min; ** = mg/min.

Rhythm strip analysis found that 2 patients were in NSR or sinus tachycardia, and 1 patient was in a paced rhythm. One patient had 12 lead ECG changes consistent with left atrial enlargement, and left ventricular hypertrophy, and all patients had T wave ECG changes. Cardiac enzymes during the late postoperative period continued to be elevated (Table 4.39).

Table 4.39

Cardiac Enzymes in the Late Postoperative Period

	N	μ	SD	Range
LDH	3	1011.47	853.09	332.00-1969.00
CK	2	336.05	447.59	20.00- 653.00
CKMB	1	28.00	-----	-------
FRCKMB	1	.05	-----	-------

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

FiO_2 and PEEP ventilatory requirements continued to decrease during the late postoperative period, with little variability in arterial PO_2. Table 4.40 shows measures of respiratory function. Average number of patient days intubated was 18.29 (N = 3, SD = 4.06, range 14.46 to 22.55 days).

Table 4.40

Respiratory Parameters in the Late Postoperative Period

	N	μ	SD	Range
FiO2	3	.31	.03	.28- .33
FiO2SE	3	.02	.01	.01- .02
PO2	3	95.54	22.73	70.83-115.56
PO2SE	3	15.08	9.40	7.54- 25.61
PEEP	3	3.25	1.70	1.66- 5.05
PEEPSE	3	.24	.22	.10- .49
ETT	3	18.29	4.06	14.46- 22.55

Note. FiO_2 = Fraction of inspired oxygen; SE = Standard error; PO_2 = Partial pressure of oxygen in mmHg; PEEP = Positive end expiratory pressure in cmH_20; ETT = Number of days intubated.

Renal function in the late postoperative phase improved with a mean serum creatinine level of 116.35 umol/L (N = 3, SD = 7.41, range 108 to 121 umol/L). However, BUN and total bilirubin remained elevated

(Table 4.41).

Table 4.41

Renal and Hepatic Function in the Late Postoperative Period

	N	μ	SD	Range
Creatinine	3	116.35	7.41	108.00-121.00
BUN	3	23.49	5.83	17.50- 29.20
U/O	3	204.07	24.73	176.30-223.73
U/OSE	3	136.10	53.75	91.61-195.81
TBili	3	77.30	44.96	47.00-129.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Hematological status of the patients was stable throughout the late postoperative period as shown in Table 4.42. PTINR returned to normal for these 3 patients.

Table 4.42

Hematological Parameters during Late Postoperative Period

	N	μ	SD	Range
Hgb	3	128.28	6.37	123.00-135.00
Hct	3	.37	.03	.35- .41
PTT	3	29.01	5.80	23.20- 34.80
Plt	3	163.28	93.13	63.00-246.00
CT Loss	3	5.39	3.81	1.25- 8.76
CTSE	3	6.44	4.13	1.74- 9.44
ACT	0	-----	----	-------
ACTSE	0	-----	----	-------
PC	3	.81	.54	.00- 1.00
FFP	3	.00	.00	-------
PltTr	3	.85	1.11	.00- 2.00
Cryo	3	.00	.00	-------

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit in L/L; PTT = Partial thromboplastin time in seconds; Plt = Platelets in thousands/mm^3; CT Loss = Chest tube loss in mls/hr; CTSE = Chest tube loss standard error; ACT = Activated clotting time in seconds; ACTSE = Activated clotting time standard error; PC = Packed cells transfused in units; FFP = Fresh frozen plasma transfused in units; PltTr = Platelets transfused in units; Cryo = Cryoprecipitate transfused in units.

The 3 patients remaining in the ICU during the late postoperative period experienced a number of infections. The most common organisms isolated included coagulase negative staphylococcus, hafnia alvei, candida albicans and tropicalis, enterococcus, enterobactor agglomerans, lactobacillus, and nonhemolytic streptococcus. Average WBC was 14.88 10^9/L (SD = 4.33, range 10.9 to 19.5 10^9/L). Mean temperature remained within normal limits (Table 4.43).

Table 4.43

Infection Status During the Late Postoperative Period

	N	**μ**	**SD**	**Range**
WBC	3	14.88	4.33	10.90-19.50
TEMP	3	36.97	.56	36.34-37.41
TEMPSE	3	.32	.04	.29- .37

Note. WBC = White blood count measured in 10^9/L; TEMP = Temperature in °C; TEMPSE = Temperature standard error.

Patient Status on Day of Hospital Discharge

Of the 7 patients who received cardiac transplants, 5 (71%) survived to hospital discharge. Table 4.44 shows neurologic and hemodynamic parameters on the day of hospital discharge.

Table 4.44

Neurologic and Hemodynamic Parameters on Day of Hospital Discharge

	N	**μ**	**SD**	**Range**
GCS	5	1.00	.00	-------
HR	5	97.33	16.63	74.00-115.00
HRSE	5	.00	.00	-------
SBP	5	119.83	21.51	95.00-150.00
SBPSE	5	.00	.00	-------
DBP	5	80.33	13.66	65.00- 98.00
DBPSE	5	.00	.00	-------
MAP	5	93.50	16.05	75.00-114.00
MAPSE	5	.00	.00	-------

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 15); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg.

Two patients (40%) remained in NSR at the time of hospital discharge, 2 patients (40%) were in sinus tachycardia, and 1 patient (20%) had sinus tachycardia with PACs. One patient (20%) continued to have evidence of past anterior ischemia/infarct on 12 lead ECG, and 3 patients (60%) had T wave changes. Cardiac enzyme levels are shown in Table 4.45.

Table 4.45

Cardiac Enzymes on Day of Hospital Discharge

	N	μ	SD	Range
LDH	3	524.33	511.37	190-1113
CK	1	24.00	.00	------
CKMB	0	-----	-----	------
FRCKMB	0	-----	-----	------

Note. LDH = Lactic dehydrogenase in U/L; CK = Creatine kinase in U/L; CKMB = Creatine kinase myocardial band; FRCKMB = Fractionated CKMB.

Respiratory function of the 5 patients was normal, with all patients on room air (FiO_2 = .21). Arterial blood gases were not available for analysis on the discharge day. Renal and hepatic function were stabilizing (Table 4.46).

Table 4.46

Renal and Hepatic Function on Day of Hospital Discharge

	N	μ	SD	Range
Creatinine	5	125.33	59.46	55.00-206.00
BUN	4	10.60	5.11	3.50- 15.30
U/O	0	-----	----	-------
U/OSE	0	-----	----	-------
TBili	3	59.00	76.45	9.00-147.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; U/O = Urine output in mls/hr; SE = Standard error; TBili = Total bilirubin measured in umol/L.

Hematological variables on the day of hospital discharge are shown in Table 4.47. PTINR was normal in 1 patient (20%) while it remained elevated in another. No patients exhibited signs of bleeding, and no patients received transfusions on their discharge day.

Table 4.47

Hematological Parameters on Day of Hospital Discharge

	N	μ	SD	Range
Hgb	5	109.17	3.87	104.00-115.00
Hct	5	.33	.02	.31- .35
PTT	1	43.50	.00	-------
Plt	5	234.50	83.79	115.00-317.00

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit in L/L; PTT = Partial thromboplastin time in seconds; Plt = Platelets in thousands/mm^3.

Measures of infection status were normal (Table 4.48), with the mean WBC equal to 6.30 10^9/L (SD = 1.59, range 3.5 to 7.9 10^9/L). Temperature ranged from 35.70 to 37.40 °C, with a mean temperature of 36.58 °C (SD = .66).

Table 4.48

Infection Status on Day of Hospital Discharge

	N	μ	SD	Range
WBC	5	6.30	1.59	3.50- 7.90
TEMP	5	36.58	.66	35.70-37.40
TEMPSE	5	.21	.52	.00- 1.27

Note. WBC = White blood count measured in 10^9/L; TEMP = Temperature in °C; TEMPSE = Temperature standard error.

Patient Status at the Present Time

Four of the 5 patients who were discharged from hospital following cardiac transplantation are currently alive. One patient deceased 781 days posttransplant due to a ruptured abdominal aortic aneurysm. Follow-up data were obtained for the remaining 4 patients at their most recent transplant clinic visit. Neurologic and hemodynamic parameters are shown in Table 4.49.

Table 4.49

Neurologic and Hemodynamic Parameters at Present Time

	N	μ	SD	Range
GCS	4	1.00	.00	-------
HR	4	101.00	22.48	76.00-120.00
HRSE	4	.00	.00	-------
SBP	4	138.25	10.91	128.00-150.00
SBPSE	4	.00	.00	-------
DBP	4	92.50	3.00	90.00- 96.00
DBPSE	4	.00	.00	-------
MAP	4	107.75	3.48	103.33-111.00
MAPSE	4	.00	.00	-------

Note. GCS = Glasgow Coma Scale, measured as a fraction (out of 15); HR = Heartrate in beats/minute; SE = Standard error; SBP = Systolic blood pressure in mmHg; DBP = Diastolic blood pressure in mmHg; MAP = Mean arterial pressure in mmHg.

Twelve lead ECGs done at the patients' most recent clinic visit showed that 2 patients (50%) remained in NSR, 1 patient (25%) was in sinus tachycardia, and 1 patient (25%) who had received a permanent pacemaker implantation was in a paced rhythm. Patients had otherwise normal ECG findings. LDH was not measured in any patients. A CK level which was done in only 1 patient (25%) was normal at 121 U/L. CKMB and fractionated CKMB were not measured. Respiratory function remained stable in all patients. Parameters of renal and hepatic function are shown in Table 4.50. One patient (25%) progressed to kidney transplantation due to the long term nephrotoxic effects of Cyclosporine.

Table 4.50

Renal and Hepatic Function at Present Time

	N	μ	SD	Range
Creatinine	4	139.00	55.08	93.00-219.00
BUN	1	8.30	.00	-------
TBili	4	28.00	30.67	7.00- 72.00

Note. Creatinine measured in umol/L; BUN measured in mg/dl; TBili = Total bilirubin measured in umol/L.

Hematological variables measured at the patients' most recent clinic visit included Hgb, Hct, and platelet count, while WBC was measured as an indicator of infection. Table 4.51 displays these variables.

Table 4.51

Hematological and Infection Status at Present Time

	N	μ	SD	Range
Hgb	4	131.50	8.96	120.00-140.00
Hct	3	.37	.03	.35- .40
Plt	3	232.00	37.59	193.00-268.00
WBC	4	6.40	3.03	3.60- 10.70

Note. Hgb = Hemoglobin in gm/L; Hct = Hematocrit in L/L; Plt = Platelets in thousands/mm^3; WBC = White blood count in 10^9/L.

Of the 7 patients who received a cardiac transplant, mean length of survival was 915.71 days (SD = 1282.66, range 0 to 3712 days). Five patients survived to hospital discharge. Three (60%) were in New York Heart Association Class (NYHA) I, and 2 (40%) were in NYHA Class II. Two out of the 5 patients (40%) returned to work. The mean number of rejection episodes per person was 3.60 (SD = 2.61, range 1 to 7). Four of the 5 patients (80%) had a Grade 1A rejection; 3 (60%) had a Grade 1B rejection; 2 (40%) had a Grade 2 rejection; 3 (60%) had a Grade 3A rejection; 2 (40%) had a Grade 3B rejection; and 1 (20%) had a Grade 4 rejection episode.

The average number of infection episodes requiring intravenous antibiotics was 1.00 (SD = 1.55, range 0 to 4), and the average number of hospital readmissions was 3.50 (SD = 3.39, range 0 to 8). Reasons for hospital readmission included cholecystitis/bile duct tumour, pericardiectomy, pacemaker implantation, transient ischemic attacks, pneumonia, osteoarthritis, esophageal stricture, and ileus. Posttransplant medications are listed in Table 4.52.

Table 4.52

Posttransplant Medications

	N	μ	SD	Range
Cyclosporine	5	490.00	227.49	300-850
Prednisone	5	17.00	18.66	5-50
Azathioprine	5	58.00	65.73	0-150
Cardizem	5	192.00	200.80	0-480
Septra	5	.25	.50	0-1
Enalapril	5	2.00	4.47	0-10
Lisinopril	5	4.00	8.94	0-20
Amlodipine	5	2.00	4.47	0-10
Sotolol	5	16.00	35.78	0-80
ASA	5	64.00	35.78	0-80
Ranitidine	5	180.00	67.08	150-300
Metoclopromide	5	12.00	26.83	0-60
Lovastatin	5	3.00	4.47	0-10
Fluconazole	5	40.00	89.43	0-200
Furosemide	5	4.00	8.94	0-20

Note. Septra in tablets/day; All other medications in mg/day.

Factors Affecting Posttransplant Outcomes

Pearson's correlation coefficients were computed to determine what specific factors were related to posttransplant outcomes. These outcomes were measured in terms of survival to transplantation; number of days of patient survival following transplantation; survival to hospital discharge; patients' current status as alive or deceased; return to work; NYHA functional class; number of episodes of rejection or infection; and number of hospital readmissions.

Patient demographics, device-related data, and donor variables were analyzed with respect to posttransplant outcomes, in addition to repeated measures of hemodynamic status; respiratory, renal, hepatic, and hematological function; and infection-related parameters. Posttransplant outcomes were correlated to these variables at several time intervals throughout the transplant course. These time intervals were: 1) the day prior to VAD insertion, 2) the day of VAD insertion, 3) the transplant waiting period, 4) the day of transplant, 5) the early and late postoperative periods, 6) the time of hospital discharge, and 7) the present. Though Pearson's correlation coefficients were calculated for all variables with all outcomes, only statistically significant ($p < .05$) relationships will be discussed.

Patient Demographics Affecting Posttransplant Outcomes

Several patient demographic variables were significantly correlated to posttransplant outcomes (Table 4.53). Patient age was inversely related to number of posttransplant rejection episodes ($r = -.5767$, $p = .010$), while gender was positively correlated to the number of infection episodes ($r = .5197$, $p = .027$). Younger patients survived for longer periods of time following transplantation, and had more rejection episodes, while females had a greater number of posttransplant infection episodes. Those patients who were in cardiogenic shock ($r = .5383$, $p = .014$), and on VAD support for longer periods of time pretransplant ($r = .5629$, $p = .010$), had an increased length of survival posttransplant, and subsequently more rejection episodes ($r = .5468$, $p = .015$). The presence of a pretransplant cardiac arrest was significantly related to a decreased chance of survival to hospital discharge, a decreased chance of survival to the present time, a decreased functional ability according to NYHA classification, and an increased chance of returning to work following hospital discharge. Patient body surface area; blood group; diagnosis; reason for VAD insertion; number or type of previous cardiac surgeries and cardiopulmonary bypass times; VAD name or type; presence of an IABP; ejection fraction; smoking history; alcohol abuse; and CMV status had no significant relationship to posttransplant outcomes.

Table 4.53

Relationships Between Patient Demographics and Posttransplant Outcomes

OUCOMES: **DEMOGRAPHICS:**

	Age	Gender	Shock Duration	Cardiac Arrest	VAD Hours
Timetx	-.6719** (p=.001)	.0376 (p=.875)	.5383* (p=.014)	-.1032 (p=.665)	.5629* (p=.010)
DC	-.2654 (p=.258)	.2182 (p=.355)	.2654 (p=.258)	-.6417** (p=.002)	.2832 (p=.226)
Status	.2858 (p=.222)	.0000 (p=1.000)	-.4113 (p=.072)	.7276** (p=.000)	-.4335 (p=.056)
RTW	.0774 (p=.753)	-.3997 (p=.090)	.0798 (p=.746)	.4947* (p=.031)	.0757 (p=.758)
NYHA	.3316 (p=.166)	-.2582 (p=.286)	-.2323 (p=.339)	.5455* (p=.016)	-.2501 (p=.302)
Reject	-.5767** (p=.010)	.0787 (p=.749)	.5182* (p=.023)	-.3545 (p=.136)	.5468* (p=.015)
Infect	.0199 (p=.937)	.5197* (p=.027)	-.3727 (p=.128)	-.0625 (p=.805)	- .3977 (p=.102)

Note. * $p < .05$; ** $p < .01$
Age in years; Shock duration in hours; VAD Hours = Number of hours supported on ventricular assist device; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association Functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes.

Donor Variables Affecting Recipient Posttransplant Outcomes

Variables including donor age, donor CMV status, and amount of donor inotropic support were significantly related to recipient posttransplant outcomes (Table 4.54). Recipients who received older donor organs were less likely to be currently alive than patients who received younger organs ($r = .8947$, $p = .007$). Recipients of CMV positive organs experienced fewer numbers of infectious episodes than those who received CMV negative organs ($r = -.9487$, $p = .004$). Patients who received organs from donors on high doses of Dopamine were more likely to survive to hospital discharge and subsequently, experienced more episodes of infection. These patients were less likely to return to work following their transplant, were in poorer NYHA functional class, and were more likely to be deceased at the current time. Recipients of organ donors receiving high doses of Norepinephrine were less likely to return to work following transplantation ($r = -.4975$, $p = .030$). Donor ischemic time, blood group, gender, and amount of

Epinephrine infusion were not significantly correlated with recipient posttransplant outcomes.

Table 4.54

Relationships Between Donor Variables and Posttransplant Outcomes

OUTCOMES: DONOR VARIABLES:

	Donor Age	Donor CMV	Donor Norepinephrine Dose	Donor Dopamine Dose
Tx	---	---	.3126 (p=.180)	.8172** (p=.000)
DC	-.5784 (p=.174)	-.2582 (p=.576)	.3504 (p=.130)	.6023** (p=.005)
Status	.8947** (p=.007)	-.4714 (p=.286)	-.3974 (p=.083)	-.5169* (p=.020)
RTW	.3616 (p=.425)	.4201 (p=.348)	-.4975* (p=.030)	-.8163** (p=.000)
NYHA	.4909 (p=.263)	.3475 (p=.445)	-.3014 (p=.210)	-.6141** (p=.005)
Infect	.2835 (p=.586)	.9487** (p=.004)	.1715 (p=.496)	.5043* (p=.033)

Note. * $p < .05$; ** $p < .01$
--- = Unable to calculate correlation coefficient; Tx = Received a cardiac transplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association Functional class; Infect = Number of infection episodes.

Patient Hemodynamic Status Prior to VAD Insertion

Several hemodynamic parameters measured prior to insertion of the VAD were significantly correlated to posttransplant outcomes (Table 4.55). Increased variability of the cardiac output/index and pulmonary/systemic resistance over the 24 hour period prior to VAD insertion was significantly related to increased length of survival posttransplant and to the present, and an increased number of rejection episodes. A significantly higher mean pulmonary vascular resistance was present in patients who received a transplant ($r = .7608$, $p = .017$). Sinus bradycardia present in patients prior to VAD insertion was negatively related to current status and return to work following transplantation.

Table 4.55

Relationships Between Pre-VAD Hemodynamic Parameters and Posttransplant Outcomes

OUTCOMES: HEMODYNAMIC PARAMETERS:

	COSE	**CISE**	**PVRI**	**PVRSE**	**SVRSE**	**SBRAD**
Tx	.5000 (p=.170)	.5000 (p=.170)	.7608* (p=.017)	.5000 (p=.170)	.5000 (p=.170)	.3469 (p=.146)
Timetx	.9778** (p=.000)	.9778** (p=.000)	.5782 (p=.103)	.9778** (p=.000)	.9778** (p=.000)	.1196 (p=.626)
Status	-1.000** (p=.000)	-1.000** (p=.000)	-.5972 (p=.090)	-1.000** (p=.000)	-1.000** (p=.000)	-.4564* (p=.049)
RTW	-.3536 (p=.351)	-.3536 (p=.351)	-.1801 (p=.643)	-.3536 (p=.351)	-.3536 (p=.351)	-.6063** (p=.008)
Reject	.8535** (p=.003)	.8535** (p=.003)	.4924 (p=.178)	.8535** (p=.003)	.8535** (p=.003)	.0066 (p=.979)

Note. * $p < .05$; ** $p < .01$
COSE = Cardiac output standard error; CISE = Cardiac index standard error; PVRI = Pulmonary vascular resistance index; PVRSE = Pulmonary vascular resistance index standard error; SVRSE = Systemic vascular resistance index standard error; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; Status = Alive or deceased; Reject = Number of rejection episodes.

Inotropic Support Prior to VAD Insertion

Prior to VAD insertion, patients were on numerous inotropes. Being on numerous inotropes was significantly related to increased length of survival posttransplant (r = .4516, p = .046). Dopamine, Dobutamine, Norepinephrine, and SNP were found to be correlated to posttransplant outcomes. Dopamine infused at a rate of 5 to 10ug/kg/min was positively related to length of survival posttransplant (r = .6162, p = .005). Patients who were on Dopamine for a greater number of hours were more likely to receive a transplant, survive longer following transplant, and have a greater number of rejection episodes. Increased duration of Dopamine infusion was negatively related to current status and NYHA functional class (Table 4.56).

Dobutamine infusions at higher rates (> 10ug/kg/min) were related to increased incidence of transplantation, increased length of survival posttransplant, survival to hospital discharge, but an increased number of rejection episodes. However, those patients were less likely to be alive at the present time and had a poorer NYHA functional class.

Mean rate of Norepinephrine infusion was not significantly related to posttransplant outcomes, however a low rate of infusion of the drug was related to fewer rejection episodes (r = .4785, p = .045). High doses and longer periods of SNP infusion were related to increased length of survival posttransplant, in addition to an increased number of rejection episodes.

Table 4.56

Relationships Between Pre-VAD Inotropic Support and Posttransplant Outcomes

OUTCOMES: INOTROPES:

	# of Ino	**Dop >5<10**	**Dop Hrs**	**Dob**	**Dob Hrs**	**Norepi Lo**	**SNP**	**SNP Hrs**
Tx	.1764 (p=.457)	.0936 (p=.703)	.4788* (p=.044)	.5250* (p=.021)	.4939* (p=.032)	.3086 (p=.199)	.3086 (p=.199)	.3086 (p=.199)
Timetx	.4516* (p=.046)	.6162** (p=.005)	.6473** (p=.004)	.3938 (p=.095)	.6254** (p=.004)	.1348 (p=.582)	.9409** (p=.000)	.9409** (p=.000)
DC	.2040 (p=.388)	.1359 (p=.579)	.4788* (p=.044)	.3700 (p=.119)	.4458 (p=.052)	.3469 (p=.146)	.3469 (p=.146)	.3469 (p=.146)
Status	-.3239 (p=.164)	-.1845 (p=.450)	-.5744* (p=.013)	.4696* (p=.042)	-.5435* (p=.016)	-.3944 (p=.095)	-.3944 (p=.095)	-.3944 (p=.095)
NYHA	-.2695 (p=.265)	-.2165 (p=.388)	-.5527* (p=.021)	-.4790* (p=.044)	-.5220* (p=.026)	-.4456 (p=.064)	-.4456 (p=.064)	-.4456 (p=.064)
Reject	.4305 (p=.066)	.4359 (p=.071)	.5639* (p=.018)	.5169* (p=.028)	.5390* (p=.021)	.4785* (p=.045)	.7177** (p=.001)	.7177** (p=.001)

Note. * p <.05; ** p < .01
# of Ino = Number of inotropes; Dop >5<10 = Dopamine infusion >5<10ug/kg/min; Dop Hrs = Number of hours of Dopamine infusion; Dob = Dobutamine infusion; Dob Hrs = Number of hours of Dobutamine infusion; Norepi Lo = Lowest dose of Norepinephrine infused; SNP = Sodium Nitroprusside infusion; SNP Hrs = Number of hours of SNP infusion; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = survival to hospital discharge; Status = Alive or deceased; NYHA = New York Heart Association Functional class; Reject = Number of rejection episodes.

Respiratory, Renal, and Hematologic Factors Prior to VAD Insertion

High pre-VAD PO_2 and increased variability over a 24 hour period of FiO_2 were significantly related to increased length of posttransplant survival, survival to hospital discharge, but an increased number of rejection episodes. These variables were also associated with increased incidence of survival to the present, and return to work posttransplant (Table 4.57). Increased variability in urine output over 24 hours was indicative of longer periods of survival posttransplant, survival to hospital discharge, but an increased number of rejection episodes. However, these patients were less likely to be alive at the present time, had lower NYHA functional class scores, and infrequently returned to work following surgery. Larger numbers of packed cell infusions correlated with increased length of survival postoperatively.

Table 4.57

Relationships Between Pre-VAD Respiratory, Renal, and Hematologic Factors and Posttransplant Outcomes

OUTCOMES:	**RESPIRATORY FACTORS:**		**RENAL FACTORS:**	**HEMATOLOGICAL FACTORS:**
	PO2	**FiO2SE**	**UOSE**	**Packed Cells**
Tx	**.1990 (p=.515)**	**.4533* (p=.045)**	**.2971 (p=.437)**	**.0342 (p=.886)**
Timetx	**.6812* (p=.010)**	**.7281** (p=.000)**	**.7106* (p=.032)**	**.4591* (p=.042)**
DC	**.6676* (p=.013)**	**.5081* (p=.022)**	**.7109* (p=.032)**	**.0712 (p=.766)**
Status	**-.8634** (p=.000)**	**-.5761** (p=.008)**	**-.7109* (p=.032)**	**-.1130 (p=.635)**
RTW	**-.4371 (p=.135)**	**-.4794* (p=.038)**	**-.7109* (p=.032)**	**.0094 (p=.969)**
NYHA	**-.6676* (p=.013)**	**-.5510* (p=.014)**	**-.7109* (p=.032)**	**-.1365 (p=.578)**
Reject	**.7298** (p=.005)**	**.5583* (p=.013)**	**.7109* (p=.032)**	**.3130 (p=.192)**

Note. *** p < .05; ** p < .01**
PO2 = Partial pressure of inspired oxygen; FiO2SE = Fraction of inspired oxygen standard error; UOSE = Urine output standard error; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association Functional class; Reject = Number of rejection episodes.

Hemodynamic Status on Day of VAD Insertion

Increased mean systolic blood pressure and variability of heart rate were related to decreased incidence of transplantation. Patients with a highly variable cardiac output/index, and pulmonary/systemic vascular resistance had a greater incidence of transplantation ($r = .7888$, $p = .020$), and a larger number of hospital readmissions ($r = .8876$, $p = .008$). High systemic vascular resistance on the day of VAD insertion was consistent with decreased length of posttransplant survival, decreased incidence of survival to hospital discharge, and decreased chance of being alive at the present time. These patients were in higher NYHA functional classes, and experienced fewer rejection episodes. Patients who were in sinus rhythm on the VAD implant day were more likely to survive for longer periods of time and return to work, however, the average NYHA functional class was poorer than in patients who were not in sinus rhythm. Survival to hospital discharge was reduced in this group of patients (Table 4.58).

Table 4.58

Relationships Between Hemodynamic Parameters on Day of VAD Insertion and Posttransplant Outcomes

OUTCOMES: HEMODYNAMIC PARAMETERS:

	HRSE	SBP	COSE	CISE	PVRI	PVRSE	SVRI	SVRSE	NSR	STACH
Tx	.4892* (p=.034)	.1709 (p=.484)	.6889 (p=.059)	.7331* (p=.039)	.7888* (p=.020)	.6084 (p=.109)	-.1158 (p=.785)	.5371 (p=.170)	.3953 (p=.104)	.3162 (p=.201)
DC	-.1473 (p=.547)	.2121 (p=.383)	.0264 (p=.951)	.1000 (p=.814)	.5729 (p=.138)	-.0432 (p=.919)	-.7412* (p=.035)	.1294 (p=.760)	-.5547* (p=.017)	.4438 (p=.065)
Timetx	-.3503 (p=.141)	.1216 (p=.620)	.0264 (p=.951)	.1000 (p=.814)	.5729 (p=.138)	-.0432 (p=.919)	-.7412* (p=.035)	-.1294 (p=.760)	-.3473 (p=.158)	.3375 (p=.171)
Status	.0549 (p=.823)	-.0418 (p=.865)	-.0264 (p=.951)	-.1000 (p=.814)	-.5729 (p=.138)	.0432 (p=.919)	.7412* (p=.035)	.1294 (p=.760)	.4781* (p=.045)	-.3287 (p=.183)
RTW	.3849 (p=.115)	-.4793* (p=.044)	-.0264 (p=.951)	-.1000 (p=.814)	-.5729 (p=.138)	.0432 (p=.919)	.7412* (p=.035)	.1294 (p=.760)	.4887* (p=.047)	-.2685 (p=.297)
NYHA	.3328 (p=.177)	-.2508 (p=.315)	-.0264 (p=.951)	-.1000 (p=.814)	-.5729 (p=.138)	.0432 (p=.919)	.7412* (p=.035)	.1294 (p=.760)	.5185* (p=.033)	-.4338 (p=.082)
Reject	-.2719 (p=.275)	.0495 (p=.845)	.0264 (p=.951)	.1000 (p=.814)	.5729 (p=.138)	-.0432 (p=.919)	-.7412* (p=.035)	.1294 (p=.760)	-.4519 (p=.069)	.5156* (p=.034)
Readmit	.1936 (p=.456)	.2943 (p=.251)	.8888** (p=.007)	.8876** (p=.008)	.6678 (p=.101)	.8431* (p=.017)	.7279 (P=.064)	.8296* (P=.021)	-.1229 (P=.650)	.1079 (P=.691)

Note. * $p < .05$; ** $p < .01$
HRSE = Heart rate standard error; SBP = Systolic blood pressure; COSE = Cardiac output standard error; CISE = Cardiac index standard error; PVRI = Pulmonary vascular resistance index; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association Functional class; Reject = Number of rejection episodes; Readmit = Number of hospital readmissions.

Inotropic Support on the Day of VAD Insertion

Table 4.59 shows the association between inotropic support on the VAD implantation day and posttransplant outcomes.

Table 4.59

Relationships Between Inotropic Support on VAD Insertion Day and Posttransplant Outcomes

OUTCOMES: INOTROPES:

	Dop Hrs	Dob	Dob Hrs	NTG	NTG Hrs	SNP	SNP Hrs	Lido
Tx	-.0461 (p=.851)	.5598* (p=.013)	.3081 (p=.199)	.1189 (p=.628)	.1356 (p=.580)	.5295* (p=.020)	.4940* (p=.032)	.1583 (p=.517)
Timetx	.4744* (p=.040)	.6218** (p=.004)	.7080** (p=.001)	.5118* (p=.025)	.5659* (p=.012)	.9292** (p=.000)	.9350** (p=.000)	-.1120 (p=.648)
DC	.0575 (p=.815)	.2680 (p=.267)	.2888 (p=.231)	.1555 (p=.525)	.2024 (p=.406)	.6088** (p=.006)	.5664* (p=.011)	-.0673 (p=.784)
Status	-.1404 (p=.567)	-.2455 (p=.311)	-.3109 (p=.195)	-.1342 (p=.584)	-.2653 (p=.272)	-.4591* (p=.048)	-.5928** (p=.007)	.3259 (p=.173)
RTW	.0688 (p=.786)	-.1975 (p=.432)	-.1857 (p=.461)	-.1619 (p=.521)	-.1887 (p=.453)	-.6228** (p=.006)	-.5436* (p=.020)	-.0975 (p=.700)
NYHA	-.1532 (p=.544)	-.3817 (p=.118)	-.3972 (p=.103)	-.2664 (p=.285)	-.3060 (p=.217)	-.7244* (p=.001)	-.6423** (p=.004)	-.0131 (p=.959)
Reject	.3653 (p=.136)	.5390* (p=.021)	.5823* (p=.011)	-.3044 (p=.219)	.4063 (p=.094)	.7991** (p=.000)	.7055** (p=.001)	-.0256 (p=.920)
Infect	-.2036 (p=.433)	.1141 (p=.663)	.0333 (p=.899)	.1124 (p=.668)	-.0363 (p=.890)	.9051** (p=.000)	.4135 (p=.099)	.4080 (p=.104)
Readmit	-.3379 (p=.185)	.0083 (p=.975)	-.0323 (p=.902)	.0060 (p=.982)	-.0933 (p=.722)	.5495* (p=.022)	.2915 (p=.256)	.5519* (p=.022)

Note. * $p < .05$; ** $p < .01$
DpHrs = Number of hours of Dopamine infusion; Dob = Dobutamine infusion; DobHrs = Number of hours of Dobutamine infusion; NTG = Nitroglycerine infusion; NTGHrs = Number of hours of NTG infusion; SNP = Sodium Nitroprusside infusion; SNPHrs = Number of hours of SNP infusion; Lido = Lidocaine infusion; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes; Readmit = Number of hospital readmissions.

Patients who received Dopamine infusions for longer periods of time on the day of VAD insertion had an increased length of survival posttransplant ($r = .4744$, $p = .040$). Patients on high doses of Dobutamine, who received the medication for longer periods of time, were more likely to receive a transplant, survive longer posttransplant, and have a greater number of rejection episodes. The presence of high doses of NTG and SNP (> 2.5ug/kg/min) correlated with increased length of survival posttransplant, while the presence of a SNP infusion on the VAD insertion day also increased the probability that the patient would receive a transplant, be discharged from hospital, be currently alive, but have increased numbers of rejection episodes, infections, and hospital readmissions. These patients were less likely to return to work posttransplant and remained in a poorer NYHA functional class. Patients who received Lidocaine during this period were more likely to have repeat hospital readmissions ($r = .5519$, $p = .022$).

Respiratory, Hepatic, and Hematologic Factors on Day of VAD Insertion

Patients with high FiO_2 requirements on the day of VAD insertion were less likely to receive cardiac transplants, and had a lower incidence of survival, with poorer functional recovery if they received a transplant. Patients with high total bilirubin levels on the day of VAD insertion survived for longer periods of time following transplant ($r = .9584$, $p = .010$). Higher hemoglobin and hematocrit levels on the VAD insertion day were associated with a decreased chance of survival to the present. Normal PTINR levels were associated with a better chance of receiving a cardiac transplant, increased length of survival after surgery, and an increased incidence of rejection ($r = -.5317$, $p = .028$). Transfusion of large amounts of FFP on the day of VAD insertion was associated with a higher incidence of postoperative infection ($r = .6663$, $p = .003$) (Table 4.60).

Table 4.60

Relationships Between Respiratory, Hepatic, and Hematologic Factors on Day of VAD Insertion and Posttransplant Outcomes

OUTCOMES:	**RESPIRATORY FACTORS:**	**HEPATIC FACTORS:**	**HEMATOLOGIC FACTORS:**			
	FiO2	**TBili**	**Hgb**	**Hct**	**PTINR**	**FFP**
Tx	-.1957 (p=.422)	.3613 (p=.550)	.1103 (p=.663)	.1546 (p=.540)	-.4725* (p=.048)	.1213 (p=.621)
Timetx	-.4629* (p=.046)	.9584* (p=.010)	.0155 (p=.951)	.0263 (p=.918)	.4899* (p=.039)	.1025 (p=.676)
DC	-.5319* (p=.019)	.5646 (p=.321)	-.4068 (p=.094)	-.3721 (p=.128)	-.2652 (p=.288)	.2877 (p=.232)
Status	.4708* (p=.042)	-.5646 (p=.321)	.5121* (p=.030)	.4722* (p=.048)	.3571 (p=.146)	.0426 (p=.863)
NYHA	.4887* (p=.040)	-.5646 (p=.321)	.1486 (p=.569)	.1075 (p=.681)	.3864 (p=.126)	-.3214 (p=.193)
Reject	-.4638 (p=.053)	.7249 (p=.166)	.0206 (p=.937)	.0502 (p=.848)	-.5317* (p=.028)	.1932 (p=.442)
Infect	-.3214 (p=.208)	---	-.0117 (p=.966)	-.0099 (p=.971)	.1528 (p=.572)	.6663** (p=.003)

Note. * $p < .05$; ** $p < .01$
FiO_2 = Fracion of inspired oxygen; TBili = Total bilirubin; Hgb = Hemoglobin; Hct = Hematocrit; PTINR = Prothrombin time; FFP = Fresh frozen plasma; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes.

Patient Neurologic and Hemodynamic Status During Transplant Waiting Period

Neurologic status of patients awaiting cardiac transplantation was an important determinant of patient outcomes. Patients who developed significant neurologic impairment (low GCS scores) during the waiting period were no longer considered to be transplant candidates. Patients with higher GCS scores were more likely to survive to hospital discharge and to be currently alive. However, these patients were less likely to return to work, had more rejection episodes, and were more likely to require hospital readmission (Table 4.61). Patients with higher GCS scores were also in better NYHA functional classes ($r = -.5290$, $p = .035$).

Variability of systolic blood pressure, and mean arterial pressure, were significantly correlated with survival to hospital discharge and to the present time, while stability of cardiac output was related to an increased number of hospital readmissions (r = -.8171, p = .025). An increased SVRI was associated with decreased length of survival posttransplant (r = -.7474, p =.021), while consistent, stable values of SVRI were related to an increased number of posttransplant hospital readmissions (r = -.8254, p = .022) (Table 4.61).

The presence of atrial fibrillation during the transplant waiting period was an important determinant of survival to hospital discharge, current status, return to work, NYHA functional class, and number of rejection episodes. Patients who experienced episodes of atrial fibrillation had an increased chance of survival to hospital discharge and to the present, decreased incidence of return to work, improved NYHA functional class, and more rejection episodes posttransplant (Table 4.61). Patients in sinus tachycardia with frequent PVCs had an increased number of hospital readmissions postoperatively (r = .5652, p = .028). No other cardiac rhythms had significant relationships to posttransplant outcomes during this time.

Evidence of anterior ischemia/infarction on 12 lead ECG during the transplant waiting period was perfectly correlated to receipt of a transplant, survival to hospital discharge with a good functional recovery, increased length of postttransplant survival, and subsequently an increased incidence of rejection episodes and hospital readmissions. These patients were not likely to return to work following transplant (r = -1.000, p = .000). An elevated fractionated CKMB was related to an increased incidence of hospital readmission following transplantation (r = .8891, p = .003) (Table 4.61).

Table 4.61

Relationships Between Neurologic and Hemodynamic Parameters During the Transplant Waiting Period and Posttranaplant Outcomes

OUTCOMES:	NEUROLOGIC PARAMETERS:	HEMODYNAMIC PARAMETERS:							
	GCS	SBPSE	MAPSE	COSE	SVRI	SVRSE	AFIB	STPVC	AINF
Tx	.7873** (p=.000)	-.3430 (p=.211)	-.3806 (p=.132)	-.6623 (p=.052)	-.3164 (p=.407)	-.5398 (p=.134)	.4507 (p=.069)	.3806 (p=.132)	1.000** (p=.000)
Timetx	.4294 (p=.085)	-.4142 (p=.125)	-.3786 (p=.134)	-.0991 (p=.800)	-.7474* (p=.021)	-.3064 (p=.423)	.1569 (p=.548)	.3558 (p=.161)	1.000** (p=.000)
DC	.4852* (p=.048)	-.5294* (p=.042)	-.4954* (p=.043)	-.4334 (p=.244)	-.4204 (p=.260)	-.2757 (p=.473)	.5401* (p=.025)	.0758 (p=.772)	1.000** (p=.000)
Status	-.4852* (p=.048)	.5294* (p=.042)	.4954* (p=.043)	.4334 (p=.244)	.4204 (p=.260)	.2757 (p=.473)	.5401* (p=.025)	-.0758 (p=.772)	-1.000** (p=.000)
RTW	-.5290* (p=.035)	.5299 (p=.051)	.4579 (p=.075)	.3718 (p=.364)	.4630 (p=.248)	.1643 (p=.697)	-.6831** (p=.004)	-.1771 (p=.512)	-1.000** (p=.000)
NYHA	-.5290* (p=.035)	.5299 (p=.051)	.4579 (p=.075)	.3718 (p=.364)	.4630 (p=.248)	.1643 (p=.697)	-.6831** (p=.004)	-.1771 (p=.512)	-1.000** (p=.000)
Reject	.5208* (p=.039)	-.5213 (p=.056)	.4579 (p=.075)	.3718 (p=.364)	-.5790 (p=.133)	.2363 (p=.573)	.5444* (p=.029)	.2378 (p=.375)	1.000** (p=.000)
Readmit	.5464* (p=.035)	.0085 (p=.978)	-.1670 (p=.552)	-.8171* (p=.025)	.0470 (p=.920)	-.8254* (p=.022)	.2912 (p=.292)	.5652* (p=.028)	1.000** (p=.000)

Note. * p < .05; ** p < .01
GCS = Glasgow coma scale; SBPSE = Systolic blood pressure standard error; MAPSE = Mean arterial pressure standard error; COSE = Cardiac output standard error; SVRI = Systemic vascular resistance index; SVRSE = Systemic vascular resistance index standard error; AFIB = Atrial fibrillation; STPVC = Sinus tachycardia with premature ventricular contractions; AINF = Anterior ischemia or infarct; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Readmit = Number of hospital readmissions.

Inotropic Support During Transplant Waiting Period

Though Dopamine dose during the transplant waiting period was not significantly related to posttransplant outcomes, number of hours on Dopamine was related to increased chance of survival to hospital discharge and to the present time (Table 4.62). Amount of Dobutamine infused (> 10ug/kg/min) and number of hours on the infusion were associated with increased chance of receiving a transplant, and increased length of survival postoperatively. Increased number of hours on an Epinephrine infusion also increased the probability that a transplant would occur (r = .6368, p = .006). Increased doses of NTG for longer periods of time during the waiting phase were also related to an increased chance of being transplanted, improved length of survival, increased number of rejection episodes and hospital readmissions, decreased chance of returning to work following transplantation, and improved NYHA functional class. Increased doses of SNP for longer periods of time were associated with increased length of survival, increased number of rejection episodes, decreased chance of returning to work, and improved NYHA functional class (Table 4.62). An increased number of hours on a Lidocaine infusion was correlated with an increased number of posttransplant hospital readmissions ($r = .5453$, $p = .036$).

Table 4.62

Relationships Between Inotropic Support During the Transplant Waiting Period and Posttransplant Outcomes

OUTCOMES:INOTROPES:

	Dop Hrs	Dob	Dob Hrs	Epi Hrs	NTG	NTG Hrs	SNP	SNP Hrs	Lido Hrs
Tx	.2669 (p=.300)	.5987* (p=.011)	.5840* (p=.014)	.6368** (p=.006)	.4883* (p=.047)	.5953* (p=.012)	.4507 (p=.069)	.4507 (p=.069)	.0844 (p=.747)
Timetx	.3312 (p=.194)	.7202** (p=.001)	.3312 (p=.194)	.3553 (p=.162)	.8331** (p=.000)	.5248* (p=.031)	.9759** (p=.000)	.9759** (p=.000)	-.1971 (p=.448)
DC	.5067* (p=.038)	.3214 (p=.208)	.2510 (p=.331)	.4463 (p=.073)	.4437 (p=.074)	.4393 (p=.078)	.5401* (p=.025)	.5401* (p=.025)	.3016 (p=.239)
Status	.5067* (p=.038)	-.3214 (p=.208)	-.2510 (p=.331)	-.4463 (p=.073)	-.4437 (p=.074)	-.4393 (p=.078)	-.5401* (p=.025)	-.5401* (p=.025)	.3016 (p=.239)
RTW	-.4434 (p=.085)	-.4594 (p=.073)	-.3778 (p=.149)	-.4472 (p=.082)	-.6191* (p=.011)	-.6307** (p=.009)	-.6831** (p=.004)	-.6831** (p=.004)	.2573 (p=.336)
NYHA	-.4434 (p=.085)	-.4594 (p=.073)	-.3778 (p=.149)	-.4472 (p=.082)	-.6191* (p=.011)	-.6307** (p=.009)	-.6831** (p=.004)	-.6831** (p=.004)	.2573 (p=.336)
Reject	.4365 (p=.091)	.5574* (p=.025)	.4647 (p=.070)	.4403 (p=.088)	.7096** (p=.002)	.6209* (p=.010)	.8006** (p=.000)	.8006** (p=.000)	-.2533 (p=.344)
Readmit	-.1965 (p=.483)	-.1485 (p=.597)	-.1475 (p=.600)	.4255 (p=.114)	.4561 (p=.087)	.6444* (p=.010)	---	---	.5453* (p=.036)

Note. * $p < .05$; ** $p < .01$
--- = Unable to calculate correlation coefficient; DopHrs = Number of hours of Dopamine infusion; Dob = Dobutamine infusion; DobHrs = Number of hours of Dobutamine infusion; EpiHrs = Number of hours of Epinephrine infusion; NTG = Nitroglycerine infusion; NTGHrs = Number of hours of NTG infusion; SNP = Sodium Nitroprusside infusion; SNPHrs = Number of hours of SNP infusion; LidoHrs = Number of hours of Lidocaine infusion; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Readmit = Number of hospital readmissions.

Respiratory, Hepatic, Hematologic, and Infection-Related Factors During Transplant Waiting Period

Though FiO_2 and PO_2 during the transplant waiting period were not significantly related to posttransplant outcomes, increased amount of PEEP was related to decreased chance of receiving a cardiac transplant ($r = -.5704$, $p = .017$). Increased total bilirubin levels were correlated to increased probability of receiving a transplant, increased length of posttransplant survival with more rejection episodes, and decreased chance of returning to work even though they experienced a good functional recovery (Table 4.63). Patients with normal PTINR levels were more likely to survive to hospital discharge and remain alive at the present time, than those with high PTINR levels. Those patients also had an improved NYHA functional class and rate of return to work, even though they had more rejection episodes. Patients who received cardiac transplants had significantly higher white blood counts ($r = .5502$, $p = .027$) during the transplant waiting period.

Table 4.63

Relationships Between Respiratory, Hepatic, Hematologic, and Infection-Related Parameters During the Transplant Waiting Period and Posttransplant Outcomes

OUTCOMES:	RESPIRATORY PARAMETERS:	HEPATIC PARAMETERS:	HEMATOLOGIC PARAMETERS:	INFECTION PARAMETERS:
	PEEP	TBili	PTINR	WBC
Tx	-.5704* (p=.017)	.8072* (p=.028)	-.3105 (p=.280)	.5502* (p=.027)
Timetx	-.4432 (p=.075)	.9225** (p=.003)	-.4702 (p=.090)	.2510 (p=.348)
DC	-.4257 (p=.088)	.3965 (p=.379)	-.8916** (p=.000)	.2602 (p=.330)
Status	.4257 (p=.088)	-.3965 (p=.379)	.8916** (p=.000)	-.2602 (p=.330)
RTW	.4223 (p=.103)	-.9493** (p=.004)	.8489 (p=.000)	-.4068 (p=.132)
NYHA	.4223 (p=.103)	-.9493** (p=.004)	.8489** (p=.000)	-.4068 (p=.132)
Reject	-.4498 (p=.080)	.9493** (p=.004)	-.8100** (p=.001)	.3712 (p=.173)

Note. * $p < .05$; ** $p < .01$
PEEP = Positive end expiratory pressure; Tbili = Total bilirubin; PTINR = Prothrombin time; WBC = White blood count; Tx = Received a cardiac transplant; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes.

Patient Neurologic and Hemodynamic Status on the Day of Transplant

Patient neurological status on the day of cardiac transplant was not significantly related to posttransplant outcomes. However, specific hemodynamic parameters measured on the transplant day did have significant correlations with outcomes. Variation in mean arterial pressure was associated with decreased numbers of rejection episodes ($r = -.7707$, $p = .043$), while increased cardiac output was related to increased length of survival posttransplant ($r = 1.000$, $p = .005$). Variability in cardiac index and systemic vascular resistance were significantly related to decreased incidence of return to work following transplantation (Table 4.64).

Table 4.64

Relationships Between Hemodynamic Parameters on the Day of Transplant and Posttransplant Outcomes

OUTCOMES: HEMODYNAMIC STATUS:

	MAPSE	**CO**	**CISE**	**PVRI**	**PVRSE**	**SVRSE**	**PACED**
Timetx	-.5793 (p=.173)	1.000** (p=.005)	.8107 (p=.228)	.9961 (p=.056)	.9869 (p=.103)	.7907 (p=.419)	-.0463 (p=.921)
RTW	-.3265 (p=.475)	-.8202 (p=.388)	.9997* (p=.015)	.7714 (p=.439)	-.7221 (p=.486)	-.9984* (p=.036)	-.4201 (p=.348)
NYHA	.3255 (p=.476)	.9877 (p=.100)	-.7039 (p=.503)	.9971* (p=.049)	-1.000** (p=.001)	.6798 (p=.524)	-.3475 (p=.445)
Reject	.7707* (p=.043)	.7168 (p=.491)	.1656 (p=.894)	.7706 (p=.440)	.8158 (p=.393)	.0327 (p=.915)	.2282 (p=.623)
Infect	.1660 (p=.753)	.4243 (p=.721)	.8776 (p=.318)	.3499 (p=.772)	.2794 (p=.820)	.8931 (p=.297)	.9487** (p=.004)

Note. * $p < .05$; ** $p < .01$
MAPSE = Mean arterial pressure standard error; CO = Cardiac output; CISE = Cardiac index standard error; PVRI = Pulmonary vascular resistance index; PVRSE = Pulmonary vascular resistance index standard error; SVRSE = Systemic vascular resistance index standard error; Paced = Paced rhythm; Timetx = Number of days of survival posttransplant; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes.

Increased pulmonary vascular resistance index and standard error were associated with higher levels of functional recovery (NYHA functional class I or II). Cardiac rhythms and cardiac enzyme levels on the transplant day were not found to be associated with posttransplant outcomes. However, those patients with a paced rhythm on the day of transplant were more likely to develop infectious complications postoperatively (r = .9487, p = .004).

Inotropic Support on the Day of Transplant

Several inotropes were instituted on the transplant day (Table 4.65) Patients who were on Dopamine at low doses were less likely to be readmitted to hospital after transplantation (r = -.9326, p = .007), while patients on Dopamine > 5 < 10ug/kg/min had an increased incidence of rejection (r = .9360, p = .002). Higher doses of Norepinephrine were related to increased incidence of hospital discharge and improved functional class following transplant. High doses of NTG were associated with increased length of survival posttransplant with an increased number of rejection episodes, while infusion of the drug for longer periods of time was also associated with an increased number of rejection episodes. High doses of SNP were related to increased length of posttransplant survival, while increased length of infusion was associated with increased numbers of infection and rejection episodes. Isoproterenol was commonly used on the day of transplant. Increased doses were correlated with increased length of posttransplant survival, but with an increased incidence of infection and rejection. Longer periods of infusion of the drug were associated with improved NYHA functional class, but also an increased number of rejection episodes. Infusion of high dose Lidocaine on the transplant day was associated with an increased incidence of postoperative infection (r = .9487, p = .004).

Table 4.65

Relationships Between Inotropic Support on the Day of Transplant and Posttransplant Outcomes

OUTCOMES: INOTROPIC SUPPORT:

	Dop	Dop >5<10	DopHi	Norepi	NTG	NTG Hrs	NTG Lo	NTG Hi	Lido	Lido Hrs
Timetx	-.2704 (p=.558)	.6240 (p=.134)	-.1382 (p=.768)	.3918 (p=.442)	.9489** (p=.001)	.6214 (p=.136)	.9667** (p=.000)	.8851** (p=.008)	-.0463 (p=.921)	.0463 (p=.921)
DC	.0766 (p=.870)	.5477 (p=.203)	.1835 (p=.694)	1.000** (p=.000)	.4525 (p=.308)	.5233 (p=.228)	.4064 (p=.366)	.5059 (p=.247)	.2592 (p=.576)	.2592 (p=.576)
NYHA	.0511 (p=.913)	-.7372 (p=.059)	-.0764 (p=.871)	-.9487** (p=.004)	-.5984 (p=.156)	-.7152 (p=.071)	-.5469 (p=.204)	-.6718 (p=.098)	-.3475 (p=.445)	-.3475 (p=.445)
Reject	-.3185 (p=.486)	.9360** (p=.002)	-.1724 (p=.712)	.5331 (p=.276)	.9167** (p=.004)	.9251** (p=.003)	.8883** (p=.008)	.9628** (p=.001)	.2282 (p=.623)	.2282 (p=.623)
Infect	-.1229 (p=.817)	.5000 (p=.313)	-.0029 (p=.996)	.4082 (p=.495)	.4727 (p=.344)	.4871 (p=.327)	.6558 (p=.157)	.4870 (p=.327)	.9487** (p=.004)	.9487** (p=.004)
Readmit	-.9326** (p=.007)	.3426 (p=.506)	-.8894* (p=.018)	-.6494 (p=.236)	.1899 (p=.719)	.2835 (p=.586)	.4114 (p=.418)	.2439 (p=.641)	.5056 (p=.306)	.5056 (p=.306)

Note. * p <.05; ** p < .01
Dop = Dopamine infusion; Dop >5<10 = Dopamine infusion >5<10ug/kg/min; DopHi = Highest dose of Dopamine infused; Norepi = Norepinephrine infusion; NTG = Nitroglycerine infusion; NTGHrs = Number of hours of NTG infusion; NTGLo = Lowest dose of NTG infused; NTGHi = Highest dose of NTG infused; Lido = Lidocaine infusion; LidoHrs = Number of hours of Lidocaine infusion; Timetx = Number of days of survival posttranpelant; DC = Survival to hospital discharge; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes; Readmit = Number of hospital readmissions.

Table 4.65

Relationships Between Inotropic Support on the Day of Transplant and Posttransplant Outcomes (cont'd)

OUTCOMES: INOTROPIC SUPPORT:

	Lido Hi	SNP	SNP Hrs	SNP Lo	SNP Hi	Isopro	Iso Hr	Iso Lo	Iso Hi
Timetx	-.0463 (p=.921)	.8675* (p=.011)	.8836** (p=.008)	.9484** (p=.001)	.7812* (p=.038)	.9320** (p=.002)	.6432 (p=.119)	.9644** (p=.000)	.9130** (p=.004)
NYHA	-.3475 (p=.445)	-.5588 (p=.192)	-.5376 (p=.213)	-.3809 (p=.399)	-.5818 (p=.171)	-.5125 (p=.240)	-.8306* (p=.021)	.3530 (p=.437)	-.5427 (p=.208)
Reject	.2282 (p=.623)	.6764 (p=.095)	.7739* (p=.041)	.6343 (p=.126)	.6335 (p=.127)	.8089* (p=.028)	.8966** (p=.006)	.7024 (p=.078)	.8192* (p=.024)
Infect	.9487** (p=.004)	.7875 (p=.063)	.9682** (p=.001)	.0000 (p=1.00)	.8192* (p=.046)	.9464** (p=.004)	.5232 (p=.287)	.0000 (p=1.00)	.9436** (p=.005)

Note. * $p < .05$; ** $p < .01$
LidoHi = Highest dose of Lidocaine infused; SNP = Sodium Nitroprusside infusion; SNPHrs = Number of hours of SNP infusion; SNPLo = Lowest dose of SNP infused; SNPHi = Highest dose of SNP infused; Isopro = Isoproterenol infusion; IsoHr = Number of hours of Isoproterenol infusion; IsoLo = Lowest dose of Isoproterenol infused; IsoHi = Highest dose of Isoproterenol infused; Timetx = Number of days of survival posttranpslant; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes.

Respiratory, Hematologic, and Infection-Related Factors on the Day of Transplant

Higher FiO_2 requirements on the transplant day were associated with a decreased incidence of survival to hospital discharge (r = -.8410, p = .018) and poor functional ability (NYHA functional class III-IV) following cardiac transplantation (r = .8723, p = .010). Patients who were on highly variable levels of PEEP throughout the day (increased PEEP standard error) had an increased length of posttransplant survival (r = .8170, p = .025)(Table 4.66).

No measures of hepatic or renal function were significantly related to posttransplant outcomes on the day of transplant, however specific hematological parameters were correlated with current status and number of rejection episodes. Patients with elevated levels of PTT were less likely to experience rejection episodes following transplantation (r = -.8563, p = .014), while patients who received large numbers of FFP transfusions were more likely to be currently alive (r = .8416, p = .018). Patients with a highly variable temperature over the 24 hour period were also more likely to be alive at the present time (Table 4.66).

Table 4.66

Relationships Between Respiratory, Hematologic, and Infection-Related Factors on the Day of Transplant and Posttransplant Outcomes

OUTCOMES:	**RESPIRATORY PARAMETERS:**		**HEMATOLOGIC PARAMETERS:**		**INFECTION PARAMETERS:**
	FIO2	**PEEPSE**	**PTT**	**FFP**	**TEMPSE**
Timetx	-.7001 (p=.080)	.8170* (p=.025)	-.6216 (p=.136)	-.1880 (p=.686)	-.5364 (p=.214)
DC	-.8410* (p=.018)	.1588 (p=.734)	-.3448 (p=.449)	-.2983 (p=.516)	-.7166 (p=.070)
Status	.4649 (p=.293)	-.4020 (p=.371)	-.0317 (p=.946)	.8416* (p=.018)	.8363* (p=.019)
NYHA	.8723* (p=.010)	-.2091 (p=.653)	.5518 (p=.199)	.1971 (p=.672)	-.2873 (p=.532)
Reject	-.7492 (p=.053)	.5202 (p=.231)	-.8563* (p=.014)	-.0959 (p=.838)	.0608 (p=.897)

Note. * $p < .05$
FiO_2 = Fraction of inspired oxygen; PEEPSE = Positive end expiratory pressure standard error; PTT = Partial thromboplastin time; FFP = Fresh frozen plasma transfusion; TEMPSE = Temperature standard error; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes.

Patient Neurologic and Hemodynamic Status During the Early Postoperative Period

Neurologic status during the early postoperative period (posttransplant day 1 to 8) was not a significant determinant of outcome following cardiac transplantation, however several hemodynamic parameters showed significant relationships with posttransplant outcomes (Table 4.67). Increased variation in heart rate during this time was correlated to poor long-term functional recovery ($r = .8028$, $p = .030$). Increased systolic BP was associated with an increased number of rejection episodes and hospital readmissions, while an increase in diastolic BP was related to improved posttransplant functional status (NYHA functional class I-II). Cardiac output/index and pulmonary/systemic vascular resistance during the early postoperative phase were not important indicators of posttransplant outcomes.

Patients who remained alive at the time of data collection had an increased incidence of supraventricular tachycardia in the early postoperative period ($r = .8597$, $p = .006$). Those patients who exhibited signs of right ventricular hypertrophy or ST elevation on 12 lead ECG analysis also had more infectious episodes following transplantation, while those with indicators of left atrial enlargement or ST depression had an increased length of posttransplant survival. The presence of T wave changes on the 12 lead ECG during the early postoperative period was associated with a decreased chance of survival to the present time ($r = -.9657$, $p = .008$). Of the cardiac enzymes measured, only an increase in CKMB levels was significantly related to an increased number of posttransplant hospital readmissions (Table 4.67).

Table 4.67

Relationships Between Hemodynamic Parameters During the Early Postoperative Period and Posttransplant Outcomes

OUTCOMES: HEMODYNAMIC PARAMETERS:

	HRSE	SBP	DBP	SVT	RVH	STDEP	T△	STEL	CKMB
Timetx	-.5144 (p=.192)	.6817 (p=.063)	.4132 (p=.309)	.3611 (p=.379)	-.0978 (p=.876)	.9687** (p=.007)	.8249 (p=.086)	.0978 (p=.876)	-.1215 (p=.846)
Status	.0855 (p=.840)	.0801 (p=.850)	.4364 (p=.280)	.8597** (p=.006)	.4082 (p=.495)	-.6124 (p=.272)	.9657** (p=.008)	.4082 (p=.495)	.4496 (p=.447)
NYHA	.8028* (p=.030)	-.6634 (p=.104)	-.8501* (p=.015)	.6316 (p=.128)	-.4910 (p=.401)	-.4910 (p=.401)	-.7533 (p=.142)	-.4910 (p=.401)	-.4948 (p=.397)
Reject	.7064 (p=.076)	.8369 (p=.019)*	.5889 (p=.164)	-.5139 (p=.238)	.2933 (p=.632)	.8432 (p=.073)	.6811 (p=.206)	.2933 (p=.632)	.2576 (p=.676)
Infect	-.3890 (p=.446)	.6629 (p=.151)	.5211 (p=.289)	.1540 (p=.771)	.9685* (p=.032)	----	.2147 (p=.785)	.9685* (p=.032)	.9052 (p=.095)
Readmit	-.5217 (p=.288)	.8372* (p=.038)	.8076 (p=.052)	.0396 (p=.941)	.9045 (p=.095)	----	.3942 (p=.606)	.9045 (p=.095)	.9862* (p=.014)

Note. * $p < .05$; ** $p < .01$
---- = Unable to calculate correlation coefficent; HRSE = Heartrate standard error; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; SVT = Supraventricular tachycardia; RVH = Right ventriuclar hypertrophy; STDEP = ST depression; STEL = ST elevation; T△ = T wave changes; CKMB = Creatine kinase myocardial band; Timetx = Number of days of survival posttransplant; Status = Alive or deceased; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes; Readmit = Number of hospital readmissions.

Inotropic Support During the Early Postoperative Period

Inotropic support during the early postoperative period was significantly related to posttransplant outcomes (Table 4.68). Increased doses of Dobutamine were associated with a higher incidence of death in patients who survived to hospital discharge ($r = .8392$, p = .009). Higher dosing ranges of the drug were related to an increased incidence of posttransplant infection. Epinephrine infusion at high rates for prolonged periods during the early postoperative phase was associated with decreased survival to hospital discharge, poor functional recovery, but fewer rejection episodes. In addition, infusion of Epinephrine for long periods was correlated with fewer hospital readmissions posttransplant (r = -.8591, p = .028).

Norepinephrine infusion at high doses for a long duration of time during this period was indicative of decreased incidence of survival to hospital discharge, and poor functional status postoperatively. Norepinephrine infusion for a long period of time was related to fewer posttransplant rejection episodes (r = -.7627, p = .046). High dose NTG and SNP infusions were associated with increased length of survival, while increased NTG doses were also related to a higher incidence of rejection (r = .8000, p = .031). Long duration SNP infusion was associated with increased numbers of rejection and infection episodes.

Isoproterenol infusion at high doses in the early postoperative period was related to an increased incidence of infection (r = .9339, p = .006) and subsequent hospital readmission (r = .8799, p = .021). Functional recovery was better in patients who were on infusions of the drug for longer periods of time, while hospital readmissions were also more frequent (Table 4.68).

Table 4.68

Relationships Between Inotropic Support During the Early Postoperative Period and Posttransplant Outcomes

OUTCOMES: INOTROPES:

	Dob	Dob Hrs	Dob Lo	Dob Hi	Epi	Epi Hrs	Epi Lo	Epi Hi	Norepi	Norepi Hrs	Norepi Lo
Timetx	.0172 (p=.968)	.1676 (p=.692)	.0601 (p=.888)	-.2426 (p=.563)	-.5384 (p=.169)	-.5903 (p=.123)	.4609 (p=.250)	- .5531 (p=.155)	-.3603 (p=.381)	-.3843 (p=.347)	-.3247 (p=.433)
DC	.2717 (p=.515)	-.1887 (p=.654)	.0873 (p=.837)	.3908 (p=.338)	-.8989** (p=.002)	.8584** (p=.006)	-.9515** (p=.000)	.8859** (p=.003)	-.8860** (p=.003)	-.8043* (p=.016)	-.7933* (p=.019)
Status	.8392** (p=.009)	.7755* (p=.024)	.5911 (p=.123)	.8859** (p=.003)	.5394 (p=.168)	.4692 (p=.241)	.6443 (p=.085)	.5160 (p=.190)	.6526 (p=.079)	.5214 (p=.185)	.5813 (p=.131)
NYHA	.1262 (p=.787)	.0454 (p=.923)	-.2247 (p=.628)	.2525 (p=.585)	.9664** (p=.000)	.9497** (p=.001)	.9866** (p=.000)	.9625** (p=.001)	.8634* (p=.013)	.8595* (p=.013)	.7718* (p=.042)
Reject	.0829 (p=.860)	-.0298 (p=.949)	.1476 (p=.752)	.1658 (p=.722)	-.8611* (p=.013)	-.9045** (p=.005)	-.7907* (p=.034)	-.8790** (p=.009)	-.5857 (p=.167)	-.7627* (p=.046)	-.5314 (p=.220)
Infect	.7306 (p=.099)	.7612 (p=.079)	.9033* (p=.014)	.6186 (p=.190)	-.6468 (p=.165)	-.6870 (p=.132)	-.5793 (p=.228)	-.6570 (p=.156)	-.4462 (p=.375)	-.4917 (p=.322)	-.3985 (p=.434)
Readmit	.5781 (p=.229)	.6194 (p=.190)	.7890 (p=.062)	.4604 (p=.358)	-.7817 (p=.066)	-.8591* (p=.028)	.7234 (p=.104)	-.7880 (p=.063)	-.5284 (p=.281)	-.4965 (p=.316)	-.4686 (p=.349)

Note. * $p < .05$; ** $p < .05$
Dob = Dobutamine infusion; Dob Hrs = Number of hours of Dobutamine infusion; DobLo = Lowest dose of Dob infused; DobHi = Highest dose of Dob infused; Epi = Epinephrine infusion; Epi Hrs = Number of hours of Epinephrine infusion; EpiLo = Lowest dose of Epinephrine infused; EpiHi = Highest dose of Epinephrine infused; Norepi = Norepinephrine infusion; Norepi Hrs = Number of hours of Norepinephrine infusion; NorepiLo = Lowest dose of Norepinephrine infused.

Table 4.68

Relationships Between Inotropic Support During the Early Postoperative Period and Posttransplant Outcomes (cont'd)

OUTCOMES:	INOTROPES: Norepi Hi	NTG	NTG Lo	NTG Hi	SNP	SNP Hrs	SNP Lo	SNP Hi
Timetx	-.3850 (p=.768)	.9381** (p=.001)	.9254** (p=.001)	.9504** (p=.000)	.9702** (p=.000)	.7597* (p=.029)	.9744** (p=.000)	.9674** (p=.000)
DC	.9471** (p=.000)	.2515 (p=.548)	.2232 (p=.595)	.2495 (p=.551)	.3277 (p=.428)	.4300 (p=.288)	.2986 (p=.472)	.3506 (p=.394)
Status	.6981 (p=.054)	-.1076 (p=.800)	-.0535 (p=.900)	-.1594 (p=.706)	-.2661 (p=.524)	-.0070 (p=.987)	-.2830 (p=.497)	-.2755 (p=.509)
RTW	.7524 (p=.051)	-.0262 (p=.955)	-.0066 (p=.989)	-.0084 (p=.986)	-.1313 (p=.779)	-.4442 (p=.318)	-.0736 (p=.875)	-.1744 (p=.708)
NYHA	.9242** (p=.003)	-.4554 (p=.304)	-.4231 (p=.344)	-.4411 (p=.322)	-.4655** (p=.004)	-.5983 (p=.156)	-.4325 (p=.333)	-.4862 (p=.269)
Reject	-.6266 (p=.132)	.8000* (p=.031)	.7803* (p=.038)	.7886* (p=.035)	.7193 (p=.068)	.6515 (p=.113)	.7169 (p=.070)	.7128 (p=.072)
Infect	.4802 (p=.335)	.7830 (p=.066)	.8099 (p=.051)	.7285 (p=.101)	.7137 (p=.111)	.9127* (p=.011)	.6492 (p=.163)	.7352 (p=.096)
Readmit	-.5691 (p=.238)	.7035 (p=.119)	.7570 (p=.081)	.6284 (p=.181)	.7510 (p=.085)	.8888* (p=.018)	.7102 (p=.114)	.7241 (p=.104)

Note. * p < .05; ** p < .05
NorepiHi = Highest dose of Norepinephrine infused; NTG = Nitroglycerine infusion; NTGHrs = Number of hours of NTG infusion; NTGLo = Lowest dose of NTG infused; NTGHi = Highest dose of NTG infused; SNP = Sodium Nitroprusside infusion; SNPHrs = Number of hours of SNP infusion; SNPLo = Lowest dose of SNP infusion; SNPHi = Highest dose of SNP infused; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes; Readmit = Number of hospital readmissions.

Table 4.68

Relationships Between Inotropic Support During the Early Postoperative Period and Posttransplant Outcomes (cont'd)

OUTCOMES:	INOTROPES: Isopro	IsoproHrs	IsoproLo	IsoproHi
NYHA	-.5267 (p=.225)	-.8754* (p=.010)	-.5256 (p=.226)	-.5556 (p=.195)
Infect	.9339** (p=.006)	.7574 (p=.081)	.9279** (p=.008)	.9374** (p=.006)
Readmit	.8799* (p=.021)	.8490* (p=.032)	.8844* (p=.019)	.8767* (p=.022)

Note. * p < .05; ** p < .01
Isopro = Isoproterenol infusion; IsoproHrs = Number of hours of Isoproterenol infusion; IsoproLo = Lowest dose of Isoproterenol infused; IsoproHi = Highest dose of Isoproterenol infused; NYHA = New York Heart Association functional class; Infect = Number of infection episodes; Readmit = Number of hospital readmissions.

Respiratory, Renal, Hepatic, Hematological, and Infection- Related Factors During the Early Postoperative Period

Though FiO_2 and PEEP requirements in the early postoperative period were not significantly related to posttransplant outcomes, an increased PO_2 was associated with improved length of survival and decreased numbers of hospital readmissions (Table 4.69). Those patients with elevated postoperative creatinine levels had a lower incidence of posttransplant infection ($r = -.8158$, $p = .048$). An improved NYHA functional class was associated with an increased urine output, and a greater incidence of survival to hospital discharge. A decline in postoperative hepatic function, as measured by increased total bilirubin levels, was associated with an increased length of posttransplant survival ($r = .8703$, $p = .024$).

Hematologic variables measured during the early postoperative period also showed significant relationships to posttransplant outcomes. Low platelet counts in the early postoperative period were associated with a decreased number of rejection episodes ($r = .9029$, $p = .005$). Though postoperative chest tube losses were not significant, large volumes of packed cell and platelet transfusions were related to increased length of posttransplant survival (Table 4.69). A decreased body temperature was indicative of fewer rejection episodes and fewer posttransplant hospital readmissions.

Table 4.69

Relationships Between Respiratory, Renal, Hepatic, Hematological, and Infection-Related Parameters During the Early Postoperative Period and Posttransplant Outcomes

OUTCOMES:	RESPIRATORY PARAMETER:	RENAL PARAMETERS:		HEPATIC PARAMETER:	HEMATOLOGIC PARAMETERS:			INFECTION PARAMETER:
	PO2	Creat	U/O	TBili	Plt	PC	PltTr	Temp
Timetx	.8338* (p=.010)	.2868 (p=.491)	.5314 (p=.175)	.8703* (p=.024)	.7838* (p=.021)	.7072* (p=.050)	.7543* (p=.031)	-.6830 (p=.062)
DC	.0908 (p=.831)	-.5378 (p=.169)	.7359* (p=.037)	.1272 (p=.810)	.2562 (p=.540)	.3652 (p=.374)	.4330 (p=.284)	-.3974 (p=.330)
NYHA	-.1678 (p=.719)	.4949 (p=.259)	-.7789* (p=.039)	-.2044 (p=.698)	-.4865 (p=.268)	- .3478 (p=.445)	-.5085 (p=.244)	.5245 (p=.227)
Reject	.4620 (p=.297)	-.3673 (p=.418)	.6133 (p=.143)	.6254 (p=.184)	.9029** (p=.005)	.4545 (p=.306)	.4176 (p=.351)	-.7776* (p=.040)
Infect	-.5373 (p=.272)	-.8158* (p=.048)	.5264 (p=.283)	-.8414 (p=.074)	-.0036 (p=.995)	.1734 (p=.743)	.4491 (p=.372)	-.5148 (p=.296)
Readmit	-.8283* (p=.042)	-.5279 (p=.282)	.3332 (p=.519)	.7828 (p=.117)	.3047 (p=.557)	-.2899 (p=.577)	.1362 (p=.797)	-.8594* (p=.028)

Note. * $p < .05$; ** $p < .01$
PO_2 = Partial pressure of oxygen; Creat = Creatinine; U/O = Urine output; Tbili = Total bilirubin; Plt = Platelet count; PC = Packed cell transfusion; PltTr = Platelet transfusion; Temp = Temperature; Timetx = Number of days of survival posttransplant; DC = Survival to hospital discharge; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes; Readmit = Number of hospital readmissions.

Patient Neurologic and Hemodynamic Status in the Late Postoperative Period

Patient neurologic and hemodynamic status in the late postoperative period (posttransplant day 9 to 34) were not significant predictors of posttransplant outcomes as they were during the early postoperative phase (Table 4.70). However, a higher Glasgow Coma Scale score in the late postoperative period was significantly related to an improved NYHA functional class ($r = -1.000$, $p = .000$). No other posttransplant outcomes were significantly related to neurologic status during the late postoperative period.

Increased variability in mean arterial pressure was related to a lower incidence of posttransplant rejection ($r = -.9995$, $p = .019$), while no other measures of hemodynamic status were statistically significant. Twelve lead ECG analysis showed that patients who were in junctional, accelerated junctional, or paced rhythms during the late postoperative phase had poor functional recovery (NYHA functional class III-IV). Patients who had episodes of ventricular tachycardia during this time survived longer following transplantation (r = 1.000, p = .006), and had a higher incidence of return to work (r = 1.000, p = .000). The presence of SVT or anterior ischemia/infarction during the late postoperative period was consistent with decreased incidence of survival to the present time (r = 1.000, p = .000). The appearance of a pattern consistent with pulmonary disease was related to decreased length of posttransplant survival, and decreased rates of return to work. The presence of ST elevation was consistent with higher incidence of posttransplant rejection (Table 4.70).

Table 4.70

Relationships Between Patient Neurologic and Hemodynamic Status During the Late Postoperative Period and Posttransplant Outcomes

OUTCOMES:	NEUROLOGIC PARAMETERS:	HEMODYNAMIC PARAMETERS:								
	GCS	MAPSE	Junc	AcJunc	VTach	SVT	Paced	AInf	Pul	STEL
Timetx	.5079 (p=.661)	-.8552 (p=.347)	-.5079 (p=.661)	-.5079 (p=.661)	1.000** (p=.006)	-.4921 (p=.672)	-.5079 (p=.661)	-.4921 (p=.672)	-.9978* (p=.042)	.8560 (p=.346)
Status	.5000 (p=.667)	-.0304 (p=.981)	-.5000 (p=.667)	-.5000 (p=.667)	-.5000 (p=.667)	1.000** (p=.000)	.5000 (p=.667)	1.000** (p=.000)	.4336 (p=.715)	.0289 (p=.982)
RTW	.5000 (p=.667)	-.8504 (p=.353)	-.5000 (p=.667)	-.5000 (p=.667)	1.000** (p=.000)	-.5000 (p=.667)	-.5000 (p=.667)	-.5000 (p=.667)	-.9972* (p=.048)	.8512 (p=.352)
NYHA	-1.000** (p=.000)	.8808 (p=.314)	1.000** (p=.000)	1.000** (p=.000)	-.5000 (p=.667)	-.5000 (p=.667)	1.000** (p=.000)	.5000 (p=.667)	.5636 (p=.619)	-.8801 (p=.315)
Reject	.8660 (p=.333)	.9995* (p=.019)	-.8660 (p=.333)	-.8660 (p=.333)	.8660 (p=.333)	.0000 (p=1.000)	-.8660 (p=.333)	.0000 (p=1.000)	-.9011 (p=.285)	.9996* (p=.018)

Note. * $p < .05$; ** $p < .01$
GCS = Glasgow Coma Scale score; MAPSE = Mean arterial pressure standard error; Junc = Junctional rhythm; AcJunc = Accelerated junctional rhythm; VTach = Ventricular tachycardia; SVT = Supraventricular tachycardia; Paced = Paced rhythm; AInf = Anterior ischemia/infarction; Pul = Pattern of chronic pulmonary disease; STEL = ST elevation; Timetx = Number of days of survival posttransplant; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes.

Inotropic Support During Late Postoperative Period

From postoperative day 9 to 34, patients were being progressively weaned off inotropic support. Patients who were on Dopamine > 5 < 10ug/kg/min or high doses of Dobutamine were less likely to survive to the present time, while those on NTG > 2.5ug/kg/min had a decreased length of survival (r = -1.000, p = .006) and decreased incidence of return to work following transplantation. Patients on NTG for a longer duration of time had an improved NYHA functional class postoperatively (r = -.9992, p = .025). Patients on large doses of Isoproterenol for increased durations of time during this period survived longer and returned to work more often after their transplants. The need for Lidocaine infusion in high doses for longer periods of time was related to increased postoperative mortality (r = 1.000, p = .000). The use of Procainamide in high doses was correlated with improved survival (r = 1.000, p = .000), while longer periods of time on the infusion were associated with a decreased incidence of survival to the present (Table 4.71). No patients received Epinephrine, Norepinephrine, Amrinone, Bretylium, or Neosynephrine infusions during the late postoperative period.

Table 4.71

Relationships Between Inotropic Support During the Late Postoperative Period and Posttransplant Outcomes

OUTCOMES: **INOTROPES:**

	Dob	NTG	NTG Hrs	Isopro	Isopro Hrs	Lido	Lido Hrs	Procan	Procan Hrs
Timetx	-.4921 (p=.672)	-1.000** (p=.006)	.5415 (p=.636)	1.000** (p=.006)	1.000** (p=.006)	-.4921 (p=.672)	.4921 (p=.672)	.4921 (p=.672)	-.4921 (p=.672)
Status	1.000** (p=.000)	.5000 (p=.667)	.4654 (p=.692)	.5000 (p=.667)	-.5000 (p=.667)	1.000** (p=.000)	1.000** (p=.000)	1.000** (p=.000)	1.000** (p=.000)
RTW	-.5000 (p=.667)	-1.000** (p=.006)	.5338 (p=.642)	1.000** (p=.000)	1.000** (p=.000)	-.5000 (p=.667)	-.5000 (p=.667)	.5000 (p=.667)	.5000 (p=.667)
NYHA	-.5000 (p=.667)	.5000 (p=.667)	-.9992* (p=.025)	-.5000 (p=.667)	-.5000 (p=.667)	.5000 (p=.667)	-.5000 (p=.667)	-.5000 (p=.667)	.5000 (p=.667)

Note. * p < .05; ** p < .01
Dob = Dobutamine infusion; NTG = Nitroglycerine infusion; NTG Hrs = Number of hours of NTG infusion; Isopro = Isoproterenol infusion; Isopro Hrs = Number of hours of Isoproterenol infusion; Lido = Lidocaine infusion; Lido Hrs = Number of hours of Lidocaine infusion; Procan = Procainamide infusion; Procan Hrs = Number of hours of Procainamide infusion; Timetx = Number of days of survival posttransplant; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class.

Renal and Hematologic Factors During the Late Postoperative Period

Few renal and hematologic factors during the late postoperative phase (day 9 to 34 posttransplant) were significantly related to posttransplant outcomes. Elevated creatinine levels during this time were indicative of increased mortality (r = -.9987, p = .032) and decreased incidence of survival to the present time (r = -.9987, p = .032). Levels of BUN and urine output were not found to be significant. Measures of coagulation such as PTINR, PTT, platelet count, and chest tube loss were also not statistically significant, however an increased number of FFP transfusions was related to an increased length of posttransplant survival (r = 1.000, p = .006) and increased incidence of return to work following hospital discharge (r = 1.000, p = .000). An increased number of platelet transfusions was related to poor functional recovery (r = .9998, p = .011). Measures of respiratory and hepatic function, and infection-related variables during the late postoperative period were not significantly related to posttransplant outcomes (Table 4.72).

Table 4.72

Relationships Between Renal/Hematological Parameters During the Late Postoperative Period and Posttransplant Outcomes

OUTCOMES:	RENAL PARAMETER:	HEMATOLOGIC PARAMETERS:	
	Creatinine	FFP Transfusion	Platelet Transfusion
Timetx	.5355 (p=.640)	1.000** (p=.006)	-.5228 (p=.650)
Status	-.9987* (p=.032)	-.5000 (p=.667)	-.4849 (p=.678)
RTW	.5432 (p=.634)	1.000** (p=.000)	-.5150 (p=.656)
NYHA	.4555 (p=.699)	-.5000 (p=.667)	.9998* (p=.011)

Note. * p < .05; ** p < .01
FFP = Fresh frozen plasma; Timetx = Number of days of survival posttransplant; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class.

Patient Status at Time of Hospital Discharge

All patients had normal neurological function on the day of hospital discharge. Increased heartrate on hospital discharge was associated with an increased likelihood of survival to the present (r = -.9573, p = .003). Normal sinus rhythm was associated with a poorer functional recovery (r = 1.000, p = .000), and decreased incidence of rejection (r = -.9102, p = .032), while sinus tachycardia was associated with an increased incidence of posttransplant infection (r = .9623, p = .038). Patients with evidence of anterior ischemia/infarction on 12 lead ECG analysis were more likely to return to work postoperatively and be in a better NYHA functional class; they were more likely to have greater numbers of rejection episodes; and they had an decreased incidence of postoperative infections (Table 4.73). Presence of an elevated LDH was related to worsening NYHA functional class (r = .9969, p = .050).

An elevation of serum creatinine was associated with a decreased number of hospital readmissions (r = -.9993, p = .001), while an elevation of total bilirubin was consistent with a decline in functional status (r = .9969, p = .050). Increased hemoglobin and hematocrit were correlated with a higher number of hospital readmissions. An elevated WBC on the day of hospital discharge was indicative of a decreased length of survival posttransplant (r = -.8676, p = .025) (Table 4.73).

Table 4.73

Relationships Between Patient Status at Time of Hospital Discharge and Posttransplant Outcomes

OUTCOMES: HEMODYNAMIC PARAMETERS:

	HR	NSR	STach	AInf	LDH	Creat	TBili	Hgb	Hct	WBC
Timetx	.1480 (p=.780)	-.4893 (p=.403)	.6421 (p=.243)	.6137 (p=.579)	.6613 (p=.540)	.2906 (p=.576)	-.5359 (p=.640)	-.2238 (p=.670)	-.3033 (p=.559)	-.8676* (p=.025)
Status	-.9573** (p=.003)	-.4082 (p=.495)	.6124 (p=.272)	----	.4307 (p=.717)	-.5712 (p=.236)	-.5664 (p=.617)	.3588 (p=.485)	.4339 (p=.390)	.3091 (p=.551)
RTW	.3162 (p=.604)	-.6667 (p=.219)	.1667 (p=.789)	1.000** (p=.000)	-.5662 (p=.617)	.1617 (p=.795)	-.4305 (p=.717)	-.1566 (p=.801)	-.1667 (p=.789)	-.5295 (p=.359)
NYHA	.4723 (p=.422)	1.000** (p=.000)	-.6667 (p=.219)	-1.000** (p=.000)	.9969* (p=.050)	.5408 (p=.347)	.9969* (p=.050)	-.4697 (p=.425)	-.5833 (p=.302)	.2492 (p=.686)
Reject	-.0992 (p=.874)	.9102* (p=.032)	.6651 (p=.221)	1.000** (p=.000)	-.9025 (p=.283)	-.2410 (p=.696)	-.8241 (p=.383)	.2631 (p=.669)	.2976 (p=.627)	-.5648 (p=.321)
Infect	-.8745 (p=.125)	-.3333 (p=.667)	.9623* (p=.038)	-1.000** (p=.000)	----	-.7569 (p=.243)		.7432 (p=.257)	.8412 (p=.159)	.2265 (p=.774)
Readmit	.8841 (p=.116)	-.7035 (p=.296)	.8704 (p=.130)	.5000 (p=.667)	----	-.9993** (p=.001)	----	.9652* (p=.035)	.9915** (p=.009)	-.1593 (p=.841)

Note. * p < .05; ** p < .01
---- = Unable to calculate correlation coefficient; HR = Heartrate; NSR = Normal sinus rhythm; STach = Sinus tachycardia; AInf = Anterior ischemia/infarction; LDH = Lactic dehydrogenase; Creat = Creatinine; Tbili = Total bilirubin; Hgb = Hemoglobin; Hct = Hematocrit; WBC = White blood count; Status = Alive or deceased; RTW = Return to work; NYHA = New York Heart Association functional class; Reject = Number of rejection episodes; Infect = Number of infection episodes.

Patient Status at Present Time

Measures of patient hemodynamic status, renal and hepatic status, hematological status, and infection status were analyzed from the patient's most recent clinic visit. Increased diastolic blood pressure was associated with a lower functional status (r = .9623, p =.038) and a lower rate of return to work posttransplant ($r = .9623$, $p = .038$). The presence of NSR on 12 lead ECG was related to a decreased incidence of return to work ($r = -1.000$, $p = .000$), a poorer functional status ($r = 1.000$, $p = .000$), a decrease in number of rejection episodes ($r = -.9623$, $p = .038$); and a rise in the number of infections ($r = 1.000$, $p = .000$). Patients in a sinus tachycardia at the present time had a greater length of posttransplant survival ($r = .9906$, $p = .009$). Those patients who required an implantable pacemaker long-term appeared to have a decreased incidence of posttransplant infection ($r = -1.000$, $p = .000$). No other variables were significantly related to posttransplant outcomes.

Predictors of Posttransplant Outcomes

Multiple regression analyses were conducted on variables with statistically significant Pearson's correlation coefficients to determine which variables were predictive of posttransplant outcomes. Groups of predictor variables were entered into multiple regression analyses with posttransplant outcomes. Demographic variables, donor variables, and hemodynamic variables were regressed with 1) receipt of a cardiac transplant; 2) length of posttransplant survival; 3) survival to hospital discharge; 4) current status; 5) return to work; 6) NYHA functional class; 7) number of infection episodes; 8) number of rejection episodes; and 9) number of hospital readmissions. Calculations were not computed on several variables due to the increased amount of error associated with the small sample size. Chi-square analyses and Fischer's exact tests were conducted on nominal data. Only statistically significant analyses ($p \leq .05$) are reported.

Patient Demographic Variables

Chi-square analysis comparing gender with type of VAD inserted showed a statistically significant difference between males and females, with males being more likely to have an LVAD or ECMO as their VAD type ($\chi^2 = 6.111$, $df = 2$, $p = .047$). Multiple regression analyses found duration of cardiogenic shock, presence of cardiac arrest, patient age, and patient gender to be predictive of length of posttransplant survival, accounting for 55.6% of the variance (Table 4.74).

Patient demographic variables also accounted for 36% of the variance in survival to hospital discharge (Table 4.75), and 54% of the variance in the patient's current status (Table 4.76). The presence of a cardiac arrest at some time during the patient's hospitalization was the most predictive indicator of length of posttransplant survival, survival to hospital discharge, and current status independent of the other patient demographic variables. Fischer's exact test confirmed that patients who had a cardiac arrest had a decreased incidence of survival to hospital discharge ($p = .018$) and were less likely to be currently alive ($p = .009$).

Table 4.74

Multiple Regression of Patient Demographic Variables with Length of Posttransplant Survival

Predictor Variables	Length of Posttransplant Survival β	SE β	Beta	*t*
Age	-2.029	7.449	-.0476	-.272
Gender	143.971	128.076	-.2035	1.124
Cardiac Arrest	-688.967	161.287	-.7360	-4.272**
Duration of Shock	-2.350	3.136	-.1427	-.749
		R^2	=	.6606
		Adjusted R^2	=	.5561
		F (4,13)	=	6.3250**

Note. ** $p < .01$

Table 4.75

Multiple Regression of Patient Demographic Variables with Survival to Hospital Discharge

Predictor	Survival to Hospital Discharge			
Variables	β	SE β	Beta	t
Age	-.0007	.0126	-.0117	-.056
Gender	.1356	.2167	.1356	.626
Cardiac Arrest	-.8756	.2729	-.6619	-3.209**
Duration of Shock	-.0047	.0053	-.2036	-.893
		R^2 =	.5134	
		Adjusted R^2 =	.3637	
		F (4,13) =	3.4290*	

Note. * $p < .05$; ** $p < .01$

Table 4.76

Multiple Regression of Patient Demographic Variables with Current Status

Predictor	Current Status			
Variables	β	SE β	Beta	t
Age	-.0031	.0096	-.0571	-.323
Gender	.1073	.1645	.1197	.652
Cardiac Arrest	.9997	.2072	.8431	4.826**
Duration of Shock	.0026	.0040	.1254	.649
		R^2 =	.6511	
		Adjusted R^2 =	.5437	
		F (4,13) =	6.0640**	

Note. ** $p < .01$

Donor Variables

When combined and analyzed together, donor ischemic time, amount of inotropic support, donor age, gender, and CMV status were found to be statistically significant predictors of receipt of a cardiac transplant, length of posttransplant survival, survival to hospital discharge, current status, return to work, NYHA functional class, number of rejection and infection episodes, and number of hospital readmissions. Donor ischemic time, donor age, gender, and CMV status accounted for 95.7% of the variance with regards to whether or not a patient received a cardiac transplant (Table 4.77). These donor variables also accounted for 93.6% of the variance in length of posttransplant survival (Table 4.78), 93.2% of the variance in survival to hospital discharge (Table 4.79), 74.0% of the variance in current status (Table 4.80), 90.1% of the variance in return to work posttransplant (Table 4.81), 92.4% of the variance in NYHA functional class (Table 4.82), 55.9% of the variance in number of rejection episodes (Table 4.83), 97.2% of the variance in number of infection episodes (Table 4.84), and 49.5% of the variance in number of hospital readmissions (Table 4.85). Patients who received a cardiac transplant were more likely to have a male donor with a prolonged ischemic time, while length of posttransplant survival, survival to hospital discharge, and NYHA functional class, were related to donor ischemic time, donor age, and donor CMV status. Ischemic time, donor age, donor gender, and amount of donor inotropic support were also predictive of the patient's current status. Patients who received organs from younger, CMV positive donors were less likely to suffer from rejection episodes, while recipients of organs from younger, female, CMV negative donors with shorter ischemic times were more likely to suffer from infections. No variables were independent predictors of the number of posttransplant hospital readmissions.

Amount of donor inotropic support was significantly related to posttransplant outcomes. Those patients who were on higher doses of Epinephrine and Dopamine had a decreased length of posttransplant survival and decreased incidence of survival to hospital discharge. Epinephrine infusion at ≥ .2 ug/kg/min and an increased rate of Dopamine infusion (> 10 ug/kg/min) accounted for 43.5% of the variance in length of posttransplant survival (Table 4.78), 52.9% of the variance in survival to hospital discharge (Table 4.79), 60.6% of the variance in current status (Table 4.80). Though patients who were on Dopamine at > 10ug/kg/min were more likely to survive to the present time, patients who were on Epinephrine at ≥ .2ug/kg/min had poorer NYHA functional recovery, but increased incidence of return to work. These patients also had fewer episodes of rejection and infection posttransplant and fewer hospital readmissions. The presence of high doses of these 2 drugs accounted for 61.7% of the variance in return to work (Table 4.81), 47.3% of the variance in NYHA functional class (Table 4.82), 42.0% of the variance in number of rejection episodes

(Table 4.83), 50.3% of the variance in number of infection episodes (Table 4.84), and 58.8% of the variance in number of posttransplant hospital readmissions (Table 4.85). All of these values were statistically significant at $p \leq .05$.

Table 4.77

Multiple Regression of Donor Variables with Cardiac Transplantation

Predictor Variables	**Cardiac Transplantation** β	**SE β**	**Beta**	***t***
Ischemic Time	**.0009**	**.0004**	**.2779**	**2.511***
Age	**.0082**	**.0048**	**.3005**	**1.712**
Gender	**-.2533**	**.0753**	**-.4468**	**-3.365****
CMV	**-.0058**	**.1484**	**-.0073**	**-.039**
		R^2 =	**.9668**	
		Adjusted R^2 =	**.9566**	
		***F* (4,13) =**	**94.6680****	

Note. *** $p < .05$; ** $p < .01$**
CMV = Cytomegalovirus.

Table 4.78

Multiple Regression of Donor Variables with Length of Posttransplant Survival

Dependent Variables	**Length of Posttransplant Survival** β	**SE β**	**Beta**	***t***
Ischemic Time	**2.180**	**.266**	**1.100**	**8.192*****
Age	**-31.199**	**3.646**	**-1.822**	**-8.558*****
Gender	**109.738**	**56.987**	**.310**	**1.926**
CMV	**-927.379**	**112.365**	**-1.862**	**-8.253*****
		R^2 =	**.9512**	
		Adjusted R^2 =	**.9361**	
		***F* (4,13) =**	**63.2910*****	
Epi ≥ .2	**-492.980**	**-397.122**	**-1.580**	**-1.241**
Dopamine Rate	**-17.959**	**29.054**	**-.387**	**-.618**
Dopamine ≥ 10	**249.567**	**366.207**	**.581**	**.681**
		R^2 =	**.5349**	
		Adjusted R^2 =	**.4352**	
		***F* (3,14) =**	**5.3660***	

Note. *** $p < .05$; ** $p < .01$; *** $p < .001$**
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.79

Multiple Regression of Donor Variables with Survival to Hospital Discharge

Predictor	Survival to Hospital Discharge			
Variables	β	SE β	Beta	t
Ischemic Time	.0023	.0039	.821	5.926***
Age	-.0470	.0053	-1.944	-8.848***
Gender	-.0677	.0831	-.135	-.815
CMV	-1.2684	.1639	-1.802	-7.740***
		R^2 =	.9480	
		Adjusted R^2 =	.9320	
		F (4,13) =	59.2290***	
Epi $\geq$ .2	-.1621	.5125	-.368	-.316
Dopamine Rate	.0265	.0375	.405	.707
Dopamine $\geq$ 10	-.0316	.4726	-.052	-.067
		R^2 =	.6121	
		Adjusted R^2 =	.5289	
		F (3,14) =	7.3630**	

Note. * $p < .05$; ** $p < .01$; *** $p < .001$;
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.80

Multiple Regression of Donor Variables with Current Status

Predictor		**Current Status**		
Variables	**β**	**SE β**	**Beta**	***t***
Ischemic Time	**-.0032**	**.0007**	**-1.268**	**-4.682*****
Age	**.0388**	**.0093**	**1.788**	**4.166****
Gender	**.3210**	**.1456**	**.716**	**2.205***
CMV	**.2743**	**.2870**	**.434**	**.956**
		R^2 =	**.8014**	
		Adjusted R^2 =	**.7403**	
		***F* (4,13) =**	**13.1170*****	
Epi ≥ .2	**-1.102**	**.4201**	**-2.787**	**-2.622***
Dopamine Rate	**-.106**	**.0307**	**-1.806**	**-3.449****
Dopamine ≥ 10	**1.126**	**.3874**	**2.070**	**2.907***
		R^2 =	**.6756**	
		Adjusted R^2 =	**.6061**	
		***F* (3,14) =**	**9.7205*****	

Note. *** $p < .05$; ** $p < .01$; *** $p < .001$**
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.81

Multiple Regression of Donor Variables with Return to Work

Predictor		**Return to Work**		
Variables	**β**	**SE β**	**Beta**	***t***
Ischemic Time	**-.0032**	**.0009**	**-.621**	**-3.713****
Age	**.0855**	**.0117**	**1.944**	**7.331*****
Gender	**-.1098**	**.1823**	**-.121**	**-.602**
CMV	**2.8224**	**.3595**	**2.206**	**7.850*****
		R^2 =	**.9242**	
		Adjusted R^2 =	**.9009**	
		***F* (4,13) =**	**39.6331*****	
Epi ≥ .2	**.4182**	**.8396**	**.522**	**.498**
Dopamine Rate	**-.0652**	**.0614**	**-.548**	**-1.062**
Dopamine ≥ 10	**-.3068**	**.7743**	**-.278**	**-.396**
		R^2 =	**.6849**	
		Adjusted R^2 =	**.6173**	
		***F* (3,14) =**	**10.1411*****	

Note. *** $p < .05$; ** $p < .01$; *** $p < .001$**
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.82

Multiple Regression of Donor Variables with NYHA Functional Class

Predictor Variables	NYHA Functional Class			
	β	SE β	Beta	*t*
Ischemic Time	-.0075	.0015	-.751	-5.140***
Age	.1579	.0199	1.841	7.949***
Gender	.1950	.3106	.110	.628
CMV	4.5141	.6124	1.809	7.371***
		R^2 =	.9422	
		Adjusted R^2 =	.9244	
		F (4,13) =	52.9867***	
Epi ≥ .2	1.6560	1.9230	1.059	.861
Dopamine Rate	.0122	.1407	.053	.087
Dopamine ≥ 10	-.6300	1.7734	-.293	-.355
		R^2 =	.5656	
		Adjusted R^2 =	.4725	
		F (3,14) =	6.0755**	

Note. * $p < .05$; ** $p < .01$; *** $p < .001$
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.83

Multiple Regression of Donor Variables with Number of Rejection Episodes

Predictor	**Number of Rejection Episodes**			
Variables	**β**	**SE β**	**Beta**	**t**
Ischemic Time	**.0054**	**.0034**	**.565**	**1.601**
Age	**-.1061**	**.0463**	**-1.284**	**-2.293***
Gender	**-.2888**	**.7230**	**-.169**	**-.399**
CMV	**-3.1091**	**1.4256**	**-1.293**	**-2.181***
		R^2 =	**.6624**	
		Adjusted R^2 =	**.5585**	
		F (4,13) =	**6.3770****	
Epi ≥ .2	**-3.5772**	**1.9419**	**-2.376**	**-1.842**
Dopamine Rate	**-.2610**	**.1421**	**-1.167**	**-1.837**
Dopamine ≥ 10	**1.7727**	**1.7907**	**.855**	**.990**
		R^2 =	**.5224**	
		Adjusted R^2 =	**.4201**	
		F (3,14) =	**5.1053***	

Note. * p < .05; ** p < .01; *** p < .001
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.84

Multiple Regression of Donor Variables with Number of Infection Episodes

Predictor	**Number of Infection Episodes**			
Variables	**β**	**SE β**	**Beta**	**t**
Ischemic Time	**-.0018**	**.0006**	**-.281**	**-3.141****
Age	**-.0632**	**.0078**	**-1.152**	**-8.115*****
Gender	**.9374**	**.1218**	**.827**	**7.699*****
CMV	**-4.5365**	**.2401**	**-2.842**	**-18.895*****
		R^2 =	**.9783**	
		Adjusted R^2 =	**.9716**	
		F (4,13) =	**146.4502*****	
Epi ≥ .2	**-4.0474**	**1.1942**	**-4.047**	**-3.389****
Dopamine Rate	**-.1998**	**.0874**	**-1.345**	**-2.287***
Dopamine ≥ 10	**3.6228**	**1.1013**	**2.632**	**3.290****
		R^2 =	**.5905**	
		Adjusted R^2 =	**.5027**	
		F (3,14) =	**6.7285****	

Note. * p < .05; ** p < .01; *** p < .001
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Table 4.85

Multiple Regression of Donor Variables with Number of Hospital Readmissions

Predictor Variables	Number of Hospital Readmissions β	SE β	Beta	t
Ischemic Time	.0022	.0062	.135	.357
Age	.0216	.0847	.152	.254
Gender	-.6904	1.3247	-.236	-.521
CMV	-1.2152	2.6121	-.295	-.465
		R^2 =	.6140	
		Adjusted R^2 =	.4952	
		F (4,13) =	5.1685*	
Epi ≥ .2	-4.7408	2.8033	-1.838	-1.691
Dopamine Rate	-.3914	.2051	-1.022	-1.909
Dopamine ≥ 10	1.1590	2.5851	.326	.448
		R^2 =	.6610	
		Adjusted R^2 =	.5883	
		F (3,14) =	9.0986**	

Note. * $p < .05$; ** $p < .01$; *** $p < .001$
CMV = Cytomegalovirus; Epi = Epinephrine; All infusions in ug/kg/min.

Variables During Transplant Waiting Period

Neurologic, hemodynamic, respiratory, renal, hepatic, and hematological variables measured during the transplant waiting period were entered into multiple regression analyses. Only length of inotropic infusion during the transplant waiting period was predictive of the number of posttransplant hospital readmissions (Table 4.86). Length of Dobutamine, Epinephrine, Nitroglycerine, and Lidocaine infusions accounted for 42.9% of the variance in number of hospital readmissions. Increased length of Dobutamine infusion was associated with decreased numbers of posttransplant hospital readmissions, while increased length of Epinephrine, Nitroglycerine, and Lidocaine infusions were predictive of increased numbers of posttransplant hospital readmissions.

Table 4.86

Multiple Regression of Length of Inotropic Infusion During Transplant Waiting Period with Number of Posttransplant Hospital Readmissions

Predictor Variables	Number of Hospital Readmissions β	SE β	Beta	t
Dobutamine	-.0628	.0745	-.1913	-.844
Epinephrine	.0585	.0535	.2687	1.093
Nitroglycerine	.0974	.0545	.4175	1.787
Lidocaine	.0933	.0611	.3318	1.527
		R^2 =	.5925	
		Adjusted R^2 =	.4295	
		F (4,10) =	3.6350*	

Note. * $p < .05$

Variables During the Early Postoperative Period

None of the variables measured on the day of cardiac transplant were predictive indicators of posttransplant outcomes. Dosage range of Nitroprusside and Isoproterenol during the early postoperative phase were associated with the number of posttransplant infection episodes and hospital readmissions. Higher ranges of Nitroprusside and Isoproterenol infusion were associated with increased numbers of infection episodes.

Presence of 12 lead ECG changes during the early postoperative period were associated with posttransplant outcomes. Patients who survived for longer periods of time after cardiac transplantation, were those patients who had T wave inversion and ST elevation on their early postoperative ECGs, however, these patients also had an increased number of rejection and infection episodes. The small sample size must be taken into consideration in interpretation of the variance accounted for with these variables. At most, a relationship to patient outcomes was supported.

Variables at Other Time Intervals During the Transplant Period

Statistically significant Pearson's correlation coefficients for neurologic, hemodynamic, respiratory, renal, hepatic, and hematological variables were entered into multiple regression analyses for the late postoperative period, day of hospital discharge, and the present time. None of these variables were predictive of posttransplant outcomes.

CHAPTER FIVE

Discussion of Findings

A description and statistical analysis of the data in this study identified the characteristics and outcomes of patients who had a ventricular assist device (VAD) inserted as a bridge to cardiac transplantation, and the factors that affected posttransplant outcomes in this population. A descriptive, correlational design was used and data were collected by retrospective chart review to examine the relationships among patient demographic variables, donor variables, device-related variables, patient hemodynamics, respiratory, renal, hepatic, hematological, and infection-related parameters, and patient outcomes. Patient outcomes included receipt of a transplant, length of posttransplant survival, New York Heart Association (NYHA) functional class, return to work, number of rejection and infection episodes, and hospital readmissions. Descriptive statistics were used to depict characteristics of the patients, and Pearson's correlation coefficients, Fischer's exact test, Chi-square, and multiple regression analyses were used to identify predictors of posttransplant outcomes.

Factors Related to Posttransplant Outcomes

Characteristics of the Subjects

Twenty patients were included in the study with the majority being male with a mean age of 48.6 years. Though the literature suggests that patients less than 50 years of age have an increased incidence of successful transplantation (Golding, Crouch, et al., 1992; Farrar, Lawson, et al., 1990), this is not the case with the patients in this study. Only 31% (4/13) of patients less than 50 years of age survived to successful transplantation, in comparison to 43% (3/7) of patients greater than 50 years of age. This finding may represent a selection bias during the initial stages of this transplant program in accepting older patients who were previously healthy with no other comorbid risk factors for the bridging procedure.

Younger patients survived for longer periods of time following transplantation, and had more rejection episodes. These findings may be attributed to a decreased number of coexistent medical problems in a younger patient population, and accordingly, a stronger immune system. This may also explain the higher incidence of rejection in the younger patients, but is most likely due to the increased length of survival. The longer a patient survives posttransplant, the greater the number of cardiac biopsies performed, and the higher the likelihood that the patient will have a biopsy positive for rejection, even though it may be very mild and clinically insignificant in nature.

Most studies in the literature have shown no significant differences in survival between males and females, and if differences did occur, males had a greater incidence of posttransplant survival (Killen et al., 1991; Magovern, 1993; Pennington, McBride, Peigh, et al., 1994; Farrar, Lawson, et al., 1990). In this study, of the 16 males, 5 survived to transplantation (31%), while 1 (6%) was successfully weaned from VAD support without a transplant. Two of the 4 females (50%) survived to transplantation. Nineteen percent of males (3/16) survived to hospital discharge and remain currently alive, while 50% of females (2/4) survived to hospital discharge, and 25% (1/4) remain currently alive. Female patients who survived to transplantation had a greater incidence of posttransplant infection, which may be related to the increased length of ICU stay with invasive monitoring lines and ventilatory support (μ = 35.0 days), compared to the males (μ = 15.8 days).

Six of the 7 patients who received a cardiac transplant had coronary artery disease (CAD), while the other patient had a dilated cardiomyopathy. Of the patients with CAD, 67% survived to hospital discharge, and 50% are currently alive. The patient with dilated cardiomyopathy also survived to hospital discharge and is currently alive. Studies addressing the etiology of heart failure in patients bridged to cardiac transplantation on VADs is contradictory, with some research findings suggesting that patients with acute ischemic events have an increased incidence of survival, and others suggesting that patients with chronic decompensation due to cardiomyopathy have increased survival rates (Cabrol, Solis, et al., 1989; Killen et al., 1991; Saperstein et al., 1995). In this study, because there is only 1 patient in the cardiomyopathy group, the findings must be interpreted with caution.

Reasons for VAD insertion including cardiogenic shock post-cardiotomy and post-myocardial infarction, and cardiac arrest were consistent with those reported in the literature (Golding, Crouch, et al., 1992). The number of previous cardiac surgical procedures was not significantly related to posttransplant outcomes, nor was the mean cardiopulmonary bypass (CPB) time. The research literature is contradictory in this area, with some studies showing poorer outcomes with a higher number of previous surgeries and long CPB times (Pennington, Farrar, et al., 1993; Farrar and Thoratec Principal Investigators, 1994; Parascandola et al., 1988; Park et al., 1986), and others showing no significant differences (Killen et al., 1991; Magovern, 1993; McBride, Swartz, et al., 1990; Pae, Miller, Matthews, et al., 1992).

An increased duration of cardiogenic shock and increased length of VAD support in this study were associated with an improvement in length of posttransplant survival, and subsequently an increased number of rejection episodes. This finding reflects attrition in the sample of those hemodynamically unstable patients with numerous complications early in the bridging procedure, while affording the more stable patients the ability to wait for a donor organ for a longer period of time. Research in this area shows that patients who can be supported on pulsatile VADs for longer periods of time in which to recover from bleeding, sepsis, renal, and hepatic dysfunction, have improved survival rates (Oaks, Pae, et al., 1991; Frazier, Macris, et al., 1994; Ashton et al., 1996). Though the presence of an intra-aortic balloon pump (IABP) provided pulsatile flow for 85% of the patients, the centrifugal pumps which are used at the University of Alberta Hospital for bridging to cardiac transplantation are not capable of providing long-term ventricular support.

The presence of a pretransplant cardiac arrest was significantly related to a decreased chance of survival to hospital discharge, a decreased incidence of survival to the present time, decreased functional ability according to NYHA classification, and an increased incidence of return to work posttransplant. Prior cardiac arrest/hemodynamic collapse has been identified in the literature as a risk factor for death following circulatory support (Reedy, Swartz, et al., 1990; Guyton et al., 1993; Joyce, Johnson, et al., 1988), therefore the findings in this study support what has been previously reported. Of particular interest is the finding that those patients who had a pretransplant cardiac arrest had an increased incidence of return to work posttransplant, despite a decrease in functional ability. Two of the 3 males (66.7%) who had a cardiac arrest and survived to hospital discharge returned to work posttransplant, while the other was retired prior to the event. One female who had a cardiac arrest and survived to hospital discharge, retired soon after the transplant procedure. Though overall the presence of a pretransplant cardiac arrest was indicative of decreased postoperative cardiac function, the patients who survived to hospital discharge were able to return to a comparable level of preoperative function.

The type of VAD used in this study was not significantly related to posttransplant outcomes which is consistent with the literature, though some research findings suggest that patients on biventricular devices have increased morbidity and mortality (Golding, Crouch, et al., 1992; Oaks, Pae, et al., 1991; Pae, Miller, Matthews, et al., 1992; Pennington, McBride, Peigh, et al., 1994). The majority of males in this study were supported on a left ventricular assist device or extracorporeal membrane oxygenation (ECMO). Smoking history and abuse of alcohol were not identified as important factors affecting posttransplant outcomes in this study.

The most common blood type in this study was A positive (45%), however blood type was not significantly related to posttransplant outcomes. Of the 7 patients who received a cardiac transplant, 57% (4/7) were A positive, 29% (2/7) were O positive, and 14% (1/7) were B positive. Seventy-five percent of the A positive patients remain alive, while 50% of those who were O positive, and 0% of those who were B positive remain alive. This finding concurs with Nakatani, Aida, Frazier, and Macris (1989) who state that patients with the B antigen survive for shorter periods of time than patients in other blood groups.

In this study, patients with blood type O positive waited for an average of 39.52 hours on the VAD, A positive waited for a mean of 45.98 hours, and B positive waited for 48.27 hours on the device. This is contradictory to research findings (Swartz et al., 1994) and to anecdotal evidence of patients on the transplant list, in which patients in the O blood group tend to wait for longer periods of time for a suitable donor organ.

Virology status of the patients was related to increased morbidity in this study, however mortality was not affected. Neurological complications, sepsis, renal failure, and bleeding, which have been frequently identified as major sequelae of VAD support (Golding, Crouch et al., 1992; Farrar, Lawson, et al., 1990; Adamson et al., 1989; Pae, Miller, & Pierce, 1989; Pierce, Hershon, et al., 1993; Masters et al., 1996) were also identified in this patient population and lead to removal of patients from the transplant list and subsequent withdrawal of VAD support in 12 patients.

Characteristics of the Donors

Donor age, donor CMV status, and amount of donor inotropic support were significantly related to posttransplant outcomes in this study. Recipients of older donor organs were less likely to survive to the present time, recipients of CMV positive organs had an increased incidence of posttransplant infection, and recipients of donor organs supported on high doses of Dopamine had an increased incidence of discharge from hospital, but poor rates of return to work, poor NYHA functional class recovery, and decreased length of survival to the present time. High Norepinephrine doses, which may be used to augment afterload in hemodynamically unstable donors, were associated with a significantly lower rate of return to work for transplant recipients (Fleischer & Baumgartner, 1996). This finding may be related to primary graft dysfunction or reperfusion injury of organs from unstable donors with borderline cardiac function.

On multiple regression analysis, donor ischemic time, donor age, donor gender, donor CMV status, and amount of donor inotropic support were predictive of receipt of a cardiac transplant, length of posttransplant survival, return to work, NYHA functional class, number of rejection and infection episodes, and hospital readmissions. Research findings by Fragomeni and Kaye (1988), English, Spratt, Wallwork, Cory-Pearce, and Wheeldon (1984), Wahlers et al. (1991), and Bourge et al. (1993) support these results, but also indicate that donor blood group other than type O is a significant determinant of poor survival rates in posttransplant patients bridged on VADs. This was not found to be significant in this study population because the majority of donors (86%) were O positive.

Patient Status Prior to VAD Insertion

Alterations in the hemodynamic status of patients prior to transplantation were common with increased standard error in cardiac output and pulmonary/systemic vascular resistance being significantly correlated to increased length of survival and increased number of rejection episodes. This finding reflects the critical nature of patients supported on VADs and the dramatic changes in hemodynamic status associated with alterations in volume and inotropic support. Patients who received cardiac transplants had significantly higher pulmonary vascular resistance which is consistent in patients with left ventricular failure and resultant elevation of left atrial pressure. Sinus bradycardia in patients prior to VAD insertion was also related to decreased length of posttransplant survival and decreased incidence of return to work which is also reflective of decreased cardiac output in patients awaiting transplantation.

The presence of numerous inotropes in patients who received cardiac transplants is indicative of the severity of illness prior to the procedure. In general, patients were supported most commonly on Dopamine, Dobutamine, Norepinephrine, and Sodium Nitroprusside (SNP) with higher doses of the drugs prior to VAD insertion being associated with increased length of survival and decreased morbidity. Perhaps these patients on high doses of inotropes were more well-perfused with a higher mean arterial pressure, therefore decreasing the incidence of hypoperfusion-related end-organ dysfunction.

A high PO_2 and increased standard error of FiO_2 were associated with the use of extracorporeal membrane oxygenation. Patients with a high PO_2 during the pre-VAD period were less likely to be suffering from pulmonary complications of left heart failure and ventilatory support such as pneumonia and pulmonary edema. Though renal failure has been described by Drinkwater and Laks (1988), Kanter, Swartz, et al. (1987), Pierce, Hershon, et al. (1993), and Golding, Crouch, et al. (1992) as a poor prognostic indicator for posttransplant survival, creatinine and blood urea nitrogen (BUN) levels in the period prior to VAD insertion were not associated with posttransplant outcomes. However, an increased standard error in urine output during this time was indicative of longer periods of posttransplant survival. An increased urine output standard error may be reflective of anuria/oliguria followed by polyuria which is the effect generated by the addition of continuous arteriovenous hemodialysis or ultrafiltration. Large numbers of packed cell infusions correlated with an increased length of postoperative survival indicating that patients with low cardiac output syndrome who are aggressively volume resuscitated may survive to transplant and have positive posttransplant outcomes (Bojar, 1994; Kaye & O'Connell, 1993).

Patient Status on the Day of VAD Insertion

Patients with a highly variable heart rate and increased mean systolic blood pressure on the day of VAD insertion were less likely to receive a transplant, while those with variations in cardiac output and pulmonary/systemic vascular resistance (SVRI) were more likely to be transplanted. High systemic resistance associated with a decrease in posttransplant survival may be related to a reflex peripheral vasoconstriction caused by a decreased cardiac output during this period. Patients in sinus rhythm, which reflects the body's normal physiological process, on the day of VAD insertion, had an increased length of posttransplant survival if they survived to hospital discharge.

On the VAD implantation day, patients who continued to require inotropic support with Dopamine and Dobutamine had an increased length of posttransplant survival. High dose SNP and Nitroglycerine (NTG) are commonly used to reduce afterload and augment cardiac output (Fleischer & Baumgartner, 1996), and were associated with an increased probability of receiving a cardiac transplant, surviving to hospital discharge and the present time, and having an increased number of rejection, infection, and hospital readmissions. Use of Lidocaine, which is an effective drug for suppression of ventricular arrhythmias with minimal adverse effects in the transplant recipient (Kaye & O'Connell, 1993), was also associated with an increased incidence of hospital readmission. This indicates that patients with arrhythmias were successfully treated, survived to hospital discharge, and subsequently experienced complications which necessitated hospital readmission.

Patients with high FiO_2 requirements on the day of VAD insertion were less likely to receive a transplant and survive postoperatively. Poor pulmonary function in patients on VAD support may be related to pneumonia, pneumothorax, pulmonary edema, or pulmonary embolism. Though high total bilirubin levels provide evidence for hepatic dysfunction in the patient supported on a VAD, patients with high total bilirubin levels on the day of VAD insertion survived for longer periods of time following transplantation. This finding may reflect an improvement in right ventricular function following implementation of VAD support, with a decrease in hepatic congestion during the perioperative course (Bojar, 1994).

Higher hemoglobin (Hgb) and hematocrit (Hct) levels on the VAD insertion day were associated with a decreased chance of survival to the present. Though patients may not be anemic prior to VAD insertion, ongoing bleeding and hemolysis may result in a decline in Hgb and Hct levels. Patients with a normal prothrombin time (PTINR) with no evidence of bleeding had an increased length of posttransplant survival. Transfusion of large amounts of fresh frozen plasma (FFP) was associated with an increased incidence of posttransplant infection which may be related to a blood-borne virus such as cytomegalovirus (CMV).

Patient Status During the Transplant Waiting Period

Patients with high scores on the Glasgow Coma Scale (GCS) were maintained on VAD support and continued to be candidates for cardiac transplantation. Only patients with normal neurological function received cardiac transplants, therefore it is expected that they would have a better NYHA functional class, a higher incidence of rejection, and more hospital readmissions than those patients with low GCS scores. In general, hemodynamic instability during the transplant waiting period was associated with a decreased length of posttransplant survival. However, stability of cardiac output during this time can be attributed to consistent VAD flows until transplantation was achieved. In addition to cardiac output, stable values of SVRI were related to an increased number of posttransplant hospital readmissions. This finding may be associated with the maintenance of adequate VAD support until the patient received a cardiac transplant, and subsequently because the patient did receive a transplant, he or she was exposed to an increased number of posttransplant complications requiring hospitalization.

Patients who received a cardiac transplant and survived to hospital discharge were likely to have experienced atrial fibrillation during the transplant waiting period, probably related to increased myocardial irritability due to high inotropic requirements, ischemia, electrolyte imbalances, and depressed myocardial function. In addition, patients with sinus tachycardia and frequent PVCs during the transplant waiting period had an increased incidence of postoperative hospital readmission. It is difficult to explain these findings, since these patients have a "normal" heart following transplantation, but it may be related to statistical error associated with the small sample size. All patients who were transplanted had evidence of an anterior infarction on 12 lead ECG prior to transplant, and subsequently a statistically significant correlation existed between the presence of an anterior infarct and increased incidence of rejection and hospital readmission. An elevation in creatine kinase myocardial band (CKMB) was also associated with an increased incidence of posttransplant hospital readmissions.

Patients who were maintained on Dopamine, Dobutamine, and Epinephrine infusions for longer durations of time during the transplant waiting period had an increased length of posttransplant survival. Though the drug doses were not significant, these inotropes probably assisted to optimize cardiac function and maintain end-organ perfusion in the patient awaiting transplantation. Increased doses of vasodilators which decrease afterload were also associated with improved length of posttransplant survival. Patients on Lidocaine for extended periods during this time had a higher incidence of posttransplant hospital readmission, though there are no clear reasons for this finding.

Patients who required increased levels of PEEP (due to excessive bleeding or respiratory failure) during the transplant waiting period were not likely to receive a cardiac transplant. Increased total bilirubin levels which may be associated with right heart failure and subsequent hepatic congestion were correlated with an increased incidence of transplantation and length of posttransplant survival. Though these patients had a good functional recovery, they had a decreased incidence of return to work which may be related to a long postoperative recovery time in patients with multi-organ dysfunction. Patients with normal PTINR levels during the transplant waiting period had an increased incidence of survival to hospital discharge which may be associated with decreased incidence of coagulopathy and bleeding (Bojar, 1994), while patients with a high white blood count (WBC), which commonly signifies infection in patients with indwelling devices and invasive lines (Didisheim et al., 1989; Lonchyna et al., 1992), were likely to receive cardiac transplants.

Patient Status on the Day of Transplantation

Hemodynamic stability on the day of cardiac transplantation, which signified good function of the new heart, was related to increased length of posttransplant survival. Variation in mean arterial pressure (MAP), cardiac index (CI), SVRI, and pulmonary vascular resistance index (PVRI) were associated with decreased incidence of return to work, increased incidence of rejection, and improved NYHA functional class, however because of the hemodynamic consequences of CPB and donor ischemic time in the immediate postoperative period, it is difficult to establish an explanation for the relationship of these variables on the transplant day to posttransplant outcomes. Patients who required cardiac pacing in the immediate postoperative period, had an increased incidence of infectious complications, which may be related to a longer ICU stay with prolonged use of Isoproterenol infusion.

Patients on low-dose Dopamine and higher doses of Norepinephrine on the transplant day had a decreased incidence of posttransplant hospital readmissions. This may be related to the maintenance of optimal blood pressure and end-organ perfusion throughout the transplant course. Use of high dose SNP and NTG were also associated with increased posttransplant survival, reinforcing the importance of adequate inotropic support during the immediate postoperative period in these patients. Increased numbers of rejection and infection episodes, and improved NYHA functional class, may be associated with longer ICU stay, but ultimately greater incidence of survival with good cardiac recovery.

Patients with high FiO_2 requirements on the transplant day had poor survival rates, thereby reflecting the importance of adequate patient selection criteria and denying transplantation in those patients with multi-system failure. An increased variability in PEEP level on the transplant day was associated with an increased length of posttransplant survival which is most likely associated with rapid postoperative ventilatory weaning.

A highly variable temperature on the transplant day, which was related to hypothermia in the operating room and rapid rewarming following CPB, was associated with increased length of posttransplant survival. Transplant survivors required large numbers of FFP transfusions postoperatively which was probably associated with preoperative bleeding and hemolysis in addition to the institution of CPB, however patients with increased PTT levels posttransplant had decreased numbers of rejection episodes which may reflect the attrition of those patients who continued to have uncontrollable bleeding postoperatively, ultimately resulting in death.

Patient Status During the Early Postoperative Period

During the early postoperative period, variation in heart rate and blood pressure were related to NYHA functional class and number of rejection episodes and hospital readmissions. Patients who receive cardiac transplants have higher resting heart rates due to the loss of vagal tone following cardiac denervation. If this increased heart rate cannot be maintained due to the residual effects of drugs or sinus node damage during implantation, Isoproterenol or cardiac pacing is instituted. This may account for increased variability of heart rate, and decreased long-term functional recovery.

Cyclosporine induced posttransplant systemic hypertension is often severe and refractory, and may be augmented in magnitude by cardiac denervation (Kaye & O'Connell, 1993). Long-standing hypertension often leads to left ventricular hypertrophy with evidence of diastolic dysfunction (Kaye & O'Connell, 1993), therefore an increased systolic blood pressure (BP), which was associated with an increased number of rejection episodes and hospital readmissions, is anticipated. An increase in diastolic BP, which enhances coronary perfusion, was related to improved functional status in the transplant recipient.

Increased incidence of supraventricular arrhythmias during the early postoperative period may be related to myocardial irritability as mentioned previously. Patients with right ventricular hypertrophy or ST elevation on 12 lead ECG analysis, which indicates donor heart rhythm during this phase, had more infection episodes postoperatively. These patients may have required longer ICU stays for inotropic and rhythm support, and therefore had an increased incidence of nosocomial infection. Patients with ST depression or left atrial enlargement had an increased incidence of survival, while the presence of T wave changes indicating ischemia had a decreased incidence of survival to the present time. Patients with elevated CKMB levels during the early postoperative period were more likely to require hospital readmission.

Patients who required ongoing inotropic support to augment sluggish cardiac performance during the early postoperative period had a decreased length of survival and poor functional recovery posttransplant. In addition, infusion of Epinephrine and Norepinephrine for longer periods of time was associated with decreased incidence of rejection and posttransplant hospital readmissions. As stated earlier, this may represent the group of patients who did not survive to hospital discharge. Though patients on NTG and SNP had a decreased rate of mortality, they also experienced an increased rate of morbidity which is expected in patients on long-term immunosuppressive medication. Patients on high dose Isoproterenol in the early postoperative period, which provides inotropy, an increased heartrate, a decreased pulmonary vascular resistance, and improved ventricular diastolic relaxation, had an increased incidence of infection which may be related to an increased length of ICU stay (Bojar, 1994). Though patients who were maintained on the drug for longer periods of time had an improved NYHA functional class, number of hospital readmissions were also more frequent.

An increased PO_2 during this time was indicative of improved respiratory function and ultimately improved length of survival. Elevated creatinine levels were associated with a lower rate of posttransplant infection, but this may be related to an overall decreased incidence of survival in patients with posttransplant renal dysfunction. An improved NYHA functional class was associated with greater urine output which may be the result of improved renal perfusion. Patients with an increased length of posttransplant survival continued to have elevated total bilirubin levels which were probably related to the hepatotoxic effects of immunosuppressive drugs such as Cyclosporine and Azathioprine, rather than to hepatic congestion (Rickenbacher & Hunt, 1996).

Large volumes of packed cell and platelet transfusions during the early postoperative period were associated with an increased length of posttransplant survival indicating the arrest of existing coagulopathy. Decreased platelet counts were associated with a decreased incidence of rejection which may separate those patients with ongoing bleeding and platelet dysfunction who did not survive from those who survived to their first cardiac biopsy. A decreased body temperature, which is consistent with patients on steroid therapy (Gillis, 1996), was indicative of fewer rejection episodes and fewer posttransplant hospital readmissions.

Patient Status During the Late Postoperative Period

Lack of neurological deficits during the late postoperative period correlated with improved NYHA functional class posttransplant, reflecting the fact that only patients with normal neurologic function received cardiac transplants, and those that were transplanted had good cardiac recovery. A highly variable MAP during this phase was associated with a lower incidence of posttransplant rejection, indicating that patients were initially unstable hemodynamically, with improving cardiac function over time. Patients in junctional, accelerated junctional, or paced rhythms in the late postoperative period had poorer levels of cardiac function, emphasizing the importance of atrial contraction to overall cardiac output. However, patients with episodes of ventricular tachycardia had an increased incidence of posttransplant survival and higher incidence of return to work. This finding may represent rapid correction of electrolyte or acid-base imbalances and appropriate treatment or withdrawal of arrhythmogenic agents (Kaye & O'Connell, 1993).

The presence of anterior ischemia/infarction, pulmonary disease pattern, or supraventricular tachycardia (SVT) on 12 lead ECG were related to depressed myocardial performance, and therefore, decreased incidence of posttransplant survival. The presence of ST elevation was consistent with an increased incidence of posttransplant rejection. Patients who remained on inotropic support during this time period had a decreased incidence of survival, with the exception of NTG and Isoproterenol. The latter medications may have been used for extended periods to improve right heart function by venodilation with a resultant decrease in preload, and pulmonary vasodilation, with a resultant decrease in pulmonary vascular resistance. The use of Procainamide in high doses for short intervals of time was associated with an improved length of survival indicating that atrial or ventricular arrhythmias were resolved with this treatment, while Procainamide use for extended periods with inadequate arrhythmia treatment, which is a possible manifestation of acute allograft rejection (Kaye & O'Connell, 1993), was related to decreased incidence of survival.

Patients who continued to have elevated creatinine levels during the late postoperative phase, indicative of unresolved renal dysfunction, had increased posttransplant mortality. Patients who required FFP transfusions had an increased length of survival, while those who needed platelet transfusions had a poor functional recovery. Platelet transfusions are often required because of the thrombocytopenic effects of Amrinone, which is a potent inodilator that is frequently utilized to augment cardiac performance in the transplant recipient.

Patient Status at the Time of Hospital Discharge

Increased heart rate at the time of hospital discharge was associated with an increased length of survival. Increased heartrate is consistent with the normal physiology of the denervated heart (Kaye & O'Connell, 1993). Patients with normal sinus rhythm (NSR) had a decreased incidence of rejection, but a poorer functional recovery. Patients who were in sinus tachycardia at this time had an increased incidence of posttransplant infection. The correlation between sinus tachycardia and infection may signify the hyperdynamic state associated with an ongoing infectious process. Patients continued to have evidence of anterior ischemia/infarction with an increased number of rejection episodes, however they had an improved NYHA functional class, higher incidence of return to work, and fewer posttransplant infections. The presence of an elevated LDH level, which may be indicative of cardiac ischemia, was related to worsening NYHA functional class.

Despite an elevation of serum creatinine at the time of hospital discharge, these patients had a decreased number of hospital readmissions, perhaps reflecting the expertise of the care they received in the outpatient transplant clinic in medication adjustment for renal impairment. An elevation of total bilirubin related to drug-induced hepatotoxicity continued to impede functional recovery. Patients who did require hospital readmission had higher Hgb and Hct levels, indicating that anemia was not the reason for admission. An elevated WBC on the hospital discharge day was indicative of a decreased length of survival posttransplant. Rejection and infection with sources such as bacteria, viruses, fungi, parasites, or protozoa may be responsible for this WBC elevation (Love, 1996).

Patient Status at Present Time

Increased diastolic BP at the patients' most recent clinic visit was associated with a decrease in NYHA functional class and return to work. Hypertension remains a significant problem for patients on long-term Cyclosporine and continues to be treated aggressively with high doses of anti-hypertensive agents (Olivari, Antolick, & Ring, 1989; Elliott, Murphy, & Karp, 1991). Similar to the findings at the time of hospital discharge, the presence of NSR was related to poor posttransplant outcomes, while the presence of sinus tachycardia was associated to improved rates of survival. Patients with an implanted pacemaker had a decreased incidence of infection, which indicates that aseptic technique was accomplished with the insertion and maintenance of the pacemaker site.

Limitations of the Study

The use of a retrospective chart analysis with the inability to control for extraneous variables and the lack of statistical power due to the small sample size are the major limitations of this study. Though all patients bridged to cardiac transplantation on VADs from 1985 to the present were included in the study, because the patients were supported on VADs for varying amounts of time, and had different lengths of ICU and hospital stay, not all patients were included in all statistical analyses.

The inability to determine the accuracy of recorded findings, and reliance on subjective and objective data documented by health professionals involved in the patients' care also made statistical analysis and interpretation of findings questionable. However, because the entire population of patients was included, the ability to generalize the findings are relevant to this group of patients.

Implications of the Study

Difficulties exist in the ability to support patients to cardiac transplantation with the currently available devices. A method of providing improved hemodynamic stability and respiratory function during the transplant waiting period, decreasing VAD associated complications such as bleeding and renal dysfunction, and maintaining activities of daily living and psychosocial well-being would improve the quality of life of patients on VADs waiting for cardiac transplantation.

Though in this study, the number of patients who survived to cardiac transplantation was small, those who were stable on VAD support awaiting a donor organ had positive posttransplant outcomes. With technological advancements and the introduction of new implantable pulsatile devices, in the future, patients may be supported for long periods of time allowing for recovery of end-organ damage and decreasing the incidence of complications of VAD support. Because these patients would only take priority over other transplant candidates if they fit all recipient selection criteria, the transplant team would be confident that donor organs were being allocated to patients who had an excellent chance for recovery and long-term survival and not wasted in an attempt to salvage inappropriate transplant candidates.

Nursing professionals are an invaluable resource in caring for these patients and their families in a holistic manner, educating and advocating for them, and providing ongoing support and encouragement during the difficult transplant waiting period. If nurses at the bedside are knowledgeable and competent in their abilities to care for patients on VADs and easily recognize complications of VAD support, patient problems will be quickly identified and treated more efficiently. Furthermore, if nurses are confident that the patient has a reasonable chance for recovery with a cardiac transplant and that they are not prolonging needless pain and suffering, they will strive to ensure that the patient bridged to cardiac transplantation on a VAD has the best possible care.

This research is unique in that patients were studied longitudinally and factors were identified that were related to outcomes during several phases throughout the transplant period. This allows for easy recognition of factors affecting posttransplant outcomes and provides an impetus for patient management strategies during each particular period. In addition, because several variables are measured at several time intervals during each day to depict function of each system, a very accurate and reliable portrayal of patient status is achieved.

This study contributes to the existing knowledge by allowing comparison of data from one of the few Canadian centers to that of other transplant programs. The research findings provide the basis by which the transplant team can promote research-based practice to improve the overall care of the transplant candidate. With equivalent or enhanced results of patients bridged to transplant on VADs at this institution in comparison to other well-established programs, this transplant centre may be recognized as a Canadian center of excellence in the cardiac transplant field.

Conclusion

Several variables at different stages of the transplant process are significantly related to outcomes of patients bridged to cardiac transplantation on VADs. Patient demographics, donor variables, and measures of hemodynamic and respiratory status surrounding the time of VAD insertion and waiting period for transplantation have been most frequently identified as significant factors related to posttransplant outcomes. In addition, appropriate patient selection and quality of the device used for bridging to cardiac transplantation remain important determinants of posttransplant survival.

Rates of transplantation at the University of Alberta Hospital following VAD insertion (35%) are lower than those identified at several major American centers due to the inability of currently available devices to support patients for extended periods of time. Ideally, pulsatile devices, which are capable of long-term support and allow for treatment of patients in an outpatient setting, would enhance the quality of care patients receive and improve the ability to support patients to transplantation.

Patients most likely to benefit from bridge to transplant procedures are those who have experienced an acute anterior infarction with ongoing cardiac dysfunction, despite maximal inotropic support, and those with chronic diseases such as cardiomyopathy. Overall, males who are less than 50 years of age have improved survival rates, however, in this study, due to the small number of subjects, females had comparable rates of survival.

Patients who present prior to hemodynamic collapse and cardiac arrest, and who remain hemodynamically stable with adequate pulmonary function on VAD support, are most suitable for cardiac transplantation and experience a decreased incidence of posttransplant morbidity and mortality. Use of LVADs and short-term ECMO (less than 24 hours) improve the likelihood that patients will survive to transplantation, however, an increased number of complications including bleeding, thromboembolism, sepsis, and renal failure, which are a consequence of long-term VAD support and may necessitate removal of the patient from the transplant list, require time for resolution prior to cardiac transplantation.

In selection of future candidates for VAD insertion as a bridge to cardiac transplantation, institution of VAD support should be accomplished prior to the occurrence of a cardiac arrest, patient stability must be maintained during the period of early VAD institution, and complications of VAD support aggressively managed. In addition to the availability of pulsatile devices for long-term support, these improvements in quality of patient care are critically important to the outcomes of cardiac transplant recipients.

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APPENDIX A

International Society for Heart and Lung Transplantation Scale for Histological Grading of Endomyocardial Biopsy

GRADE	**DESCRIPTION**
0	No rejection
1A	Focal infiltrate without necrosis
1B	Diffuse but sparse infiltrate without necrosis
2	One focus only with aggressive infiltration/ focal myocyte damage
3A	Multifocal aggressive infiltrates/myocyte damage
3B	Diffuse inflammatory process with necrosis
4	Diffuse aggressive polymorphous infiltrate, ± edema, ± hemorrhage, ± vasculitis, with necrosis

(Kobashigawa, 1994)

APPENDIX B

Functional Classification Based on the Degree of Physical Activity Precipitating Cardiac Symptoms

FUNCTIONAL CLASS	NEW YORK HEART ASSOCIATION FUNCTIONAL DESCRIPTION
I	Patients with cardiac disease but with no limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitations, dyspnea, or anginal pain
II	Patients with cardiac disease resulting in slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in fatigue, palpitations, dypsnea, or anginal pain.
III	Patients with cardiac disease resulting in marked limitation of physical activity. Comfortable at rest, but less than ordinary activity causes fatigue, palpitations, dyspnea, or anginal pain.
IV	Patients with cardiac disease resulting in inability to carry on any physical activity without discomfort. Symptoms of cardiac insufficiency or of the anginal syndrome may be present even at rest. If any physical activity is undertaken, discomfort is increased.

(Sokolow & McIlroy, 1986; Chatterjee, 1991)